DOES THE MRAP MEET THE US ARMY'S NEEDS AS THE PRIMARY METHOD OF PROTECTING TROOPS FROM THE IED THREAT?

A thesis presented to the Faculty of the US Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE
General Studies

by

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Fort Leavenworth, Kansas
2009

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 12-06-2009	**2. REPORT TYPE** Master's Thesis	**3. DATES COVERED** *(From - To)* AUG 2008 – JUN 2009

4. TITLE AND SUBTITLE Does the MRAP meet the US Army's needs as the primary method of protecting troops from the IED threat?	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) CW3 Robert Russell	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301	**8. PERFORMING ORG REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT The purpose of this paper is to discuss the Improvised Explosive Device (IED) threat to the US Army and various methods used to counter this threat. The Mine Resistant Ambush Protected vehicle (MRAP) is the current method. This paper will address the US Army's needs to defeat the IED threat as well as the capabilities and limitations of the MRAP. The Secretary of Defense, Robert Gates, made the MRAP the top priority for the US military purchases, accelerating the procurement process that routinely takes ten years into nine months. This paper will answer the question: Does the MRAP meet the needs of the US Army to protect troops from IED threat? This will be answered by looking at the IED threat to determine requirements to protect troops. These requirements include protection, rapid fielding, and suportability. Non-MRAP countermeasures will be examined to determine if they meet these requirements. The MRAP will be analized to determine if the capabilities of the MRAP meet these requirements. This paper will examine facts that will show non-MRAP methods alone do not have the capacity to effectively protect troops from the IED threat.

15. SUBJECT TERMS
MRAP, IED

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. PHONE NUMBER** *(include area code)*
(U)	(U)	(U)	(U)	90	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MASTER OF MILITARY ART AND SCIENCE
THESIS APPROVAL PAGE

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the US Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

DOES THE MRAP MEET THE US ARMY'S NEEDS AS THE PRIMARY METHOD OF PROTECTING TROOPS FROM THE IED THREAT?, by CW3 Robert Russell, 90 pages.

The purpose of this paper is to discuss the Improvised Explosive Device (IED) threat to the US Army and various methods used to counter this threat. The Mine Resistant Ambush Protected vehicle (MRAP) is the current method. This paper will address the US Army's needs to defeat the IED threat as well as the capabilities and limitations of the MRAP. The Secretary of Defense, Robert Gates, made the MRAP the top priority for the US military purchases, accelerating the procurement process that routinely takes ten years into nine months. This paper will answer the question: Does the MRAP meet the needs of the US Army to protect troops from IED threat? This will be answered by looking at the IED threat to determine requirements to protect troops. These requirements include protection, rapid fielding, and suportability. Non-MRAP countermeasures will be examined to determine if they meet these requirements. The MRAP will be analized to determine if the capabilities of the MRAP meet these requirements. This paper will examine facts that will show non-MRAP methods alone do not have the capacity to effectively protect troops from the IED threat.

ACKNOWLEDGMENTS

I would like to thank my wife, Naw Eh Ywa Russell, for her support in completing this. I would also like to thank my MMAS committee members; Mr. John Irvine, Dr Jim Martin and Mr. Gregory Beck. I would also like to thank my 9C small group instructors at CGSC; Mr. William Knight, Mr. Kenneth Riggins, Mr. John Suprin, Mr. Mark Calhoun, and LTC Brian Allen. I would also like to thank Mr. Richard Owen and Mr. Garry Coleman from the MRAP PM's office for granting me an interview. I would also like to thank CW2 Kerry Murray, WO1 Mike Sanford, CW2 Jason Dunn, CW3 (R) Al Smith, and CW2 Jeff Wargo for contributing to the Blog that provided information to complete this paper. I would also like to thank CW5 Michael Anderson for helping me set up the Blog.

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ACRONYMS

APC	Armored Personnel Carrier
ASK	Armor Survivability Kit
CEXC	Counter Explosive Exploitation Cell
DOD	Department of Defense
EFP	Explosively Formed Projectile
EOCA	Explosive Ordnance Clearing Agent
EOD	Explosive Ordnance Disposal
EW	Electronic Warfare
FOB	Forward Operating Base
FSR	Field Service Representative
GPS	Global Positioning System
GTA	Graphic Training Aid
HEAT	High Explosive Anti-Tank
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IBA	Individual Body Armor
IEDs	Improvised Explosive Devices
IRA	Irish Republican Army
JCREW	Joint Counter Radio Controlled Improvised Explosive Electronic Warfare
JIEDDO	Joint Improvised Explosive Device Defeat Organization
JLTV	Joint Light Tactical Vehicle
JROC	Joint Requirements Oversight Council
MRAP	Mine Resistant Ambush Protected Vehicle
MRAP PM	Mine Resistant Ambush protected Vehicle Program Manager

MRUV	Mine Resistant Utility Vehicle
MSR	Main Supply Route
MTOE	Modified Table of Organization and Equipment
NATO	North Atlantic Treaty Organization
PLS	Palletized Load System
RCIED	Radio Controlled Improvised Explosive Device
RDECOM	Research, Development, and Engineering Command
REP	Competitive Request Proposal
RPG	Rocket Propelled Grenade
TARDEC	Tank, Automotive, and Armament Command Research, Development, and Engineer Center
TNT	Trinitrotoluene
USSOCOM	US Special Operations Command
VBIED	Vehicle Borne Improvised Explosive Device
VOIED	Victim Activated Improvised Explosive Device

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CHAPTER 1

INTRODUCTION

The problem is that the U. S. Army has suffered many casualties from Improvised Explosive Device (IED) attacks in their operations in Iraq and Afghanistan. The primary vehicle used to transport troops at the beginning of the conflict, the High Mobility Multipurpose Wheeled Vehicle, (HMMWV) has no IED protection. The US Army has utilized many different approaches to protect troops and counter the IED threat. The first approach used was to add additional protection to the HMMWV, using sand bags and then additional armor plate, initially this armor plate was fabricated in the field, later factory produced kits were utilized. Efforts were also made to improve soldiers' individual body armor. These proved ineffective. The US Army next provided training to all forces deploying on lessons learned on how to avoid IED strikes and how to react when attacked by an IED. The US Army also used electronic and thermal devices to interfere with the triggering mechanism used to detonate the IEDs. The US Army replaced all unarmored HMMWVs, which had armor kits applied, with up-armored HMMWVs, which were designed to provide protection against small arms, not IEDs. These up-armored HMMWVs also proved ineffective. Another approach was to use specialized personnel, or experts. An example of this is the use of engineers for route clearance, Explosive Ordnance Disposal (EOD) personnel to analyze IED fragments to identify information about the IED fabricator, and the efforts of Joint IED Defeat Organization (JEIDDO). US Army troops were still dying from IEDs. Another solution was required. The US Army turned to the MRAP.

Research Question

The primary research question is: Does the MRAP meet the US Army's needs as the primary method of protecting troops from Improvised Explosive Devices? The first secondary question is: What is the IED threat and, what are the requirements to effectively counter it? The second secondary question is: What are the Non-MRAP IED countermeasures employed by the US Army, and what are their capabilities? The third secondary is: What is the MRAP, and what are its capabilities? These questions will help answer the primary question by comparing the requirements to effectively counter the IED threat with the capabilities of the non-MRAP countermeasures and those of the MRAP. Examining the history of the MRAP will assist in identifying capabilities. Examining the accelerated acquisition process used to procure the MRAP will also be useful in identifying capabilities. The numerous models of the MRAP will also be examined. The future of the MRAP is beyond the scope of this paper, however it is recognized that the US Army will most likely face insurgents in the future who will use the IED as their weapon of choice.

Assumptions

It is assumed that the US Army will continue to be engaged in counterinsurgency operations, and that these insurgents will continue to use the improvised explosive devise as the decisive weapon in their arsenal.

Definition of Terms

IED, Improvised Explosive Device, is a bomb constructed and deployed in ways other than in conventional military action. It may be partially comprised of conventional

military explosives, such as an artillery round, attached to an improvised detonating mechanism. It may also be a military land mine, either anti-personnel or anti-tank with an improvised or conventional trigger.

MRAP, Mine Resistant Ambush Protected, a family of armored fighting vehicles designed to survive IED attacks and ambushes. MRAP vehicles usually have a "V" shaped hull to deflect away any explosive force originating below the vehicle. The axle and wheel assemblies are designed to blow off the vehicle to assist in deflecting the IED blast. The troop compartments are designed to protect troops from the explosive force. This paper will address all MRAP vehicles regardless of service to include US Army, Air Force, Marines and Special Operations.

HMMWV, High Mobility Multipurpose Wheeled Vehicle, four-wheel drive vehicle used by the US Army since 1985 for troop transport. There are 17 variants. The standard variant, also known as the M998, transports four personnel, and their equipment. The most common variant has no armor protection.

US Army, when this paper refers to the US Army, it is including all military forces that are threatened by the IED. Since the US Army is most likely to encounter this threat, the US Army has been cited.

Limitations

This paper will focus primarily on the MRAP materiel solution to the US Army's response to protect the troops from the IED threat. This paper will also focus on the US Army's needs in the current operations in Iraq and Afghanistan. This paper will not speculate about the MRAP's future.

All the information contained in this paper is unclassified, open sourced, and readily available to the public.

Scope and Delimitations

Significance of the study: The results of this paper will provide US Army personnel information about the history of the MRAP program. This paper will also provide decision makers with an understanding of the needs of the US Army that have resulted in the MRAP program, as well as some of the effects that the MRAP program has had on the US Army and may have in the future.

Delimitations: This paper will not look in detail at all counter IED methods that have been developed, but will look at the general categories of added protection, added training, electronic countermeasures and use of experts, and provide examples of each category.

Conclusions

Improvised explosive devices have caused a majority of the causalities in the US Army in their activities in Iraq and Afghanistan. Since MRAPs have been fielded there has been a significant decrease in IED causalities, with some sources attributing as much as a 90 percent decrease to the MRAP. Other non-MRAP counter-measures undoubtedly contributed to this decrease, but the MRAP appears to have had the greatest impact. The MRAP is meeting the US Army’s needs to protect troops from IEDs.

CHAPTER 2

LITERATURE REVIEW

The previous chapter discussed some of the questions that will assist in determining the suitability of the MRAP as the primary method of protecting troops from IEDS. This chapter will look at existing professional writings and publications that will address some of these secondary questions. This review of existing professional writings will be divided into three sections. The first section will discuss the IED threat. The second section will discuss IED counter-measures other than the MRAP. The third section will discuss the MRAP. Comparing the IED threat with the MRAP capability will provide a basis to answer the primary question. Examining the other non-MRAP counter-measures will further assist in this effort.

IED Threat

Graphic Training Aid (GTA) 90-10-044, *Multi-National Corps Iraq Theatre IED & Explosive Hazards Awareness Guide* dated February 2005 discusses the initial US Army response to the IED threat (Headquarters, Department of the Army 2005). This circular was used to train troops deploying to Iraq and states that an IED can be disguised to look like any object and may have complicated triggers, with a design only limited by the maker's imagination and expertise. The graphic training aid also discusses risk mitigation measures.

An article by John Ringquist titled "Challenger in Military Engineer Operations: Ten Soldier's Experience in Iraq 2003-2007," discusses the IED threat (Ringquist 2007). This article describes engineer operations in Iraq. It states that before the collapse of the

Saddam Hussein regime, there were no plans for engineer units to deal with IEDs. The engineer effort's focus in 2003 was on clearing minefields, UXO [unexploded ordinance], creating lanes in obstacles and mobility operations. By 2004 many units were conducting IED identification classes.

An article on Military Periscope.com, titled "Urban Warfare's Most Sinister Weapons," by Andy Oppenheimer provides a description of an IED (Oppenheimer 2006). It states that one definition of an IED is a bomb or mine made from homemade explosives. The makeshift nature of the IED may lead some to believe that they are simple. This is not true. The article compares the IEDs in Iraq to those produced by the Irish Republican Army (IRA) in Ireland.

The book *Conventional Ammunition in Surplus*, has a chapter titled Improvised Explosive Devices (IEDs): An Introduction written by Adrian Wilkinson, James Bevan, and Ian Biddle (Bevan, 2009). The book describes how in autumn, 2003, United States military commanders estimated that Iraq military sites contained between 600,000 and 1,000,000 tons of ammunition and explosives in over 130 ammunition storage sites. This is in addition to 10,000 cache sites discovered later in 2004. In November 2004, the United States Defense Intelligence Agency reported that the majority of explosives used in IEDs came from pilfered Iraqi ammunition stockpiles. In December 2003, there were only 250,000 tons partially secured. (Bevan, 2009).

An article in *USA Today*, titled "Insurgents adapt to US defenses faster than military adjusts to IEDs," written by Peter Eisler (2007) discusses the experiences of Army Captain Partick Murphy, who arrived in Iraq in June 2003 and left in 2004. Captain Murphy stated that the placement of IEDs, the way they were triggered, and the

explosives employed, were constantly changing. A Government Office of Accountability, (GOA), report cited by Eisler states that "not securing these conventional munitions storage sites has been costly, the looted materials have given insurgents ammunition to construct IEDs . . . and maintain the level of violence" (Eisler 2007, A11).

The Center for Army Lessons Learned and titled *TF IED Export Brief* (CGSC Staff Group 2006). This is in the form of a 95-slide PowerPoint presentation. The purpose of this presentation was to respond to a request by the Rapid Equipping Force to provide insights and solutions to the mission of paring of "convoy operations" and "improvised explosive devices." The presentation provides descriptions of common IEDs, and describes how they are emplaced.

"An Asymmetric Threat Invokes Strategic Leader Initiative: The Joint Improvised Explosive Device Defeat Organization" by John Bokel states that initially IEDs did not concern military forces. The threat following the end of major combat was loosely coordinated direct fire, small arms engagements. The overwhelming firepower of US forces forced the enemy to adjust their tactics. Indirect fire attacks, primarily from mortars and rockets was the next enemy tactic. These attacks targeted US forward operating bases (FOBs) and Iraq government facilities. US forces countered with effective counter-battery fire. Insurgents changed tactics to employ the IED. (Bokrl 2007).

Non-MRAP IED Countermeasures

The next section will examine other methods used to protect US Army personnel from the IED threat. If it can be demonstrated that the US Army's attempts to counter the

IED threat through other methods were less than successful, then there is support for the position that the MRAP is the best method of protecting troops from the IED threat.

A good description of the U.S Army's early responses to the IED threat is found in an article by Peter Eisler, Tom Vanden Brook and Blake Morrison in the *USA Today* titled "Anti-IED drills improve, but not every soldier goes through them" (Eisner et al. 2007). This article states that the Army began "substantive" service wide IED training in May of 2004, six months after IED attacks reached a level of 100 every month. Training support packages were released from the Army's Training and Doctrine Command, and updated as often as every two months. These updates attempted to keep pace with changes in the IED threat. Some of this training occurred at one of the three major combat training centers where US Army brigades conduct their pre-deployment training. Problems with this training identified in the article include practicing without armored vehicles or with surrogate vehicles that attempt to replicate the vehicles they will be operating in combat. These surrogates are not top-heavy, and lack the electronic equipment and other tools used to avoid and survive IEDs in combat. The article quotes Marine Corps Lt. Gen. James Mattis, who appeared before Congress regarding IED training. He stated "units are challenged in their readiness by equipment needs, and lack of time to train" (Eisner et al. 2007). Many are not able to train with the equipment they will use in combat because there is only enough equipment to supply the troops actually in combat. The article indicates that the US Army's training efforts have been effective. The documentation used to support this is that in the "early" months almost every IED strike resulted in casualties, but as of the date of the article, November 2007, only one in

six IED strikes result in casualties. The Pentagon also reports that over one half of all IEDs are detected, before they are detonated, and neutralized (Eisner et al. 2007).

"Improvised Explosive Devices a Multifaceted Threat" by Robert Ackerman states that the fight against IEDs has shifted focus, from primarily protecting troops from the effects of the blast to preventing the detonation and breaking up the terrorist cells that plant the IEDs (Ackerman 2008). Counter-IED work has many fronts. One is to mitigate the effect of the IED, another to prevent their use or stopping their emplacement. When the JIEDDO (Joint IED Defeat Organization) was established in 2006, 80 percent of its funds went into mitigation or prevention. JIEDDO now states that the key to stopping IED attacks is disrupting terrorist cells that plant IEDs and training of forces. Currently one-half of JIEDDO funds are involved with mitigation or prevention (Ackerman 2008).

The training provided is effective because it is based on updated communication from JIEDDO teams in Iraq and Afghanistan. Training is developed that teaches war fighters how to find IEDs, use RF countermeasures and collect information that will assist in disrupting the cells that emplace the IEDs. Current training is more focused on attacking the networks that emplace the IEDs. The training provides all levels of command with the tools to accomplish this. JEIDDO has enabled US Forces to react more quickly to changes in the ways IEDs have been constructed, triggered and emplaced, so that deploying soldiers can be trained for what they will encounter (Ackerman 2008).

The article by Ackerman described one of the early responses to the IED threat as protection. Protection of the troops from the threat of the IED originally had two primary goals. The first was to provide individual soldiers with body armor. The challenge for

the US Army was to provide body armor that would provide protection from both small arms fire and IED produced shrapnel. An anonymous article in the National Guard titled "Troops to get Vests with Side Protection" (Anonymous 2006) stated that U.S troops serving in Iraq and Afghanistan would be issued improved armored vests that provide better side protection. The vest design was changed in response to IEDs that produced shrapnel. Studies had shown that these shrapnel IEDs are a significant danger to turret gunners who were exposed for the most part from the waste up (Anonymous 2006).

A 20 January 2007 article in the Boston Globe by Megan Woolhouse, titled "The next body armor design gets a show at Natick," (Woolhouse 2007) quotes a New York Times report that a secret Pentagon study found that 80 percent of the Marines who died in Iraq from wounds to the upper body could have survived if they had better body armor.

The *Body Armor IED Information Center* website has an article titled "Introduction to Body Armor for Improvised Explosive Devises (IEDs)" (Polson Enterprises 2007). The article states that shrapnel and flying debris from IEDs result in different protection requirements than what is provided by traditional body armor. Traditional bulletproof vests surround the torso or core of the individual and protect vital organs. The article continues by describing how the detonation of an IED can propel pieces of the IED, delivery vehicle, nails, steel balls, or other materials loaded in or attached to the IED, along with dirt, rocks, glass and anything else near the detonation. This wall of debris moves in a general outward vector from the blast location, and can strike the target, or anything else within range, with deadly force. Traditional bulletproof vests only protect the main torso against this debris, exposing arms and legs to life

threatening injury. A countermeasure for this is body armor that provides protection to extremities as well as the torso (Polson Enterprises 2007).

"Wear and Tear on Military Equipment" by John Higgins discusses how the IED threat in Iraq created the need for better protection Higgins 2007). The article states that many troops and family members of troops purchased body armor because military supplies were "inadequate." The article states that as of the date of the article (16 January 2007) troops were outfitted with modularized individual body armor (IBA), which protected against both bomb fragments and small arms fire.

Higgins continues with the second focus of increased protection, increased protection on vehicles. The first method used to accomplish this was to affix metal plates, the second method was to expedite vehicles designed to be armored, and eventually to design a vehicle specifically to protect from the IED threat, or the MRAP. Tactical wheeled vehicles in the Army inventory were not designed for front line combat. They were not designed to protect from IEDs. Troops responded by "up-armoring" or adding steel plates, in the field in an ad hoc manner. This was followed by programs that developed, fabricated, and installed standardized up-armor kits. Existing armored vehicle production was increased and rushed to combat (Higgins 2007).

An article by Chuck Prichard, titled "Maintenance Company goes extra mile to Protect Soldiers" discusses how the 276th Maintenance Company fabricated and installed armor plates on Army vehicles to provide protection from IEDs (Prichard 2005). Soon after combat operations began in Iraq, insurgents began targeting thin-skinned, un-armored HMMWVs (High Mobility Multipurpose wheeled Vehicle) and other non-armored cargo vehicles. The military responded by developing armor kits, but

production could not meet the demand. This could result in troops deploying to Iraq, arriving in Kuwait and then driving these vehicles with no armor into combat. This led to the confrontation with Secretary of Defense Rumsfeld regarding the use of scrap steel to armor vehicles (Prichard 2005).

The Army identifies three levels of armored vehicles. Level one offers the most protection with occupants completely enclosed in a factory-made armored vehicle that includes bullet and blast resistant glass. This is a vehicle designed to be armored. It should be noted that the armor protection in these vehicles is designed to protect from small arms fire not IED attacks. Level two offers occupants less protection with armor plating added to vulnerable areas of the body and chassis and special ballistic glass. This is a thin-skinned vehicle with a designed, factory produced, and “professionally” installed armor kit. Level three protection is commonly called “hillbilly armor.” Locally fabricated and installed steel plates, and does not include installing ballistic glass. 276th produced more than 13,000 level three armored vehicles, during their one-year tour (Prichard 2005).

Scott Gourley discusses a program called the Humvee armor survivability kit (ASK), designed to protect drivers and passengers in HMMWVs from small arms and explosive device fragments and threat in an article titled “Armor Survivability Kits” (Gourley 2004). The ASK program started with an operational needs statement from Central Command’s Combined Joint Task Force 7. This request was directed to the Tank-automotive and Armaments Command Research Development and Engineering Center (TARDEC). The lead agency identified was Army Research Laboratory (ARL); this is the research department for the Research, Development and Engineering

Command (RDECOM). The ARL has an expertise in survivability and the use of materials. ARL came up with a design that stressed survivability, and focused on the two-door variant of the HMMWV. ARL produced 40 prototype kits in October 2003. TARDEC made some minor modifications to allow for weather stripping to seal the doors and increased the thickness of the ballistic glass used. Testing was also conducted to insure soldiers would not be injured by the ASK in a vehicle crash. These improved designs were used to develop 3-D computer-aided design models necessary to feed expanded production. One hundred additional pilot kits were produced. ARL sent the first 40 kits to Iraq, with two installers, by the third week in October. The first production kits were manufactured at Anniston Army Depot and Rock Island Arsenal, each producing 500, by the middle of February 2004. As of mid-March 2004, 2,261 kits had been completed with 1,924 shipped to Iraq and 1,636 installed. TARDEC plans to complete 6,760 kits, adding level two protection to all vehicles in Iraq subject to the IED threat (Gourley 2004).

Roxana Trion states that a Navy-lead team was tasked with finding ways to defeat roadside bombs in Iraq and Afghanistan in an article titled "Counter-IED Evolution" (Tiron 2008). The Joint Counter Radio-Controlled Improvised Explosive Electronic Warfare (JCREW) has been working on this since 2005. JCREW personnel have developed jammers to block the radio frequency triggers used to remotely detonate IEDs. Cell phones, garage door openers, cordless telephones, and other radio devices used to trigger IEDs are not able to get their signal through the stronger signal broadcast by the jammers and the IED cannot detonate. As one frequency is jammed, insurgents have used other devices, and other frequencies. The latest jammers are software focused, so

the frequencies jammed can be changed by updating software and not hardware. Earlier jammers that were hardware based could interfere with frequencies used by coalition forces to communicate, and with other jamming devices, decreasing their effectiveness. They often jammed frequencies used to control bomb-disposal robots. This left troops with the choice of being able to communicate or being protected by the jammers, but not both. JCREW worked with US and allied military's to remove these conflicts. The current JCREW version, called a spiral, is 3.1 for the individually carried version and 3.2 for the vehicle mounted system. The article states that JCREW is working on a spiral 3.3 that will be mounted at a fixed site and include the more powerful hardware. All three systems would use compatible software so that the systems could be changed rapidly to adjust for changes by insurgents (Tiron 2008).

Robert Ackerman wrote an article titled "Iraq Hones Army Electronic Warfare" which discussed the US Army's electronic warfare countermeasures to the IED threat. The article starts with the statement that "the Iraq War has proven to be the mother of invention for the US Army electronic warfare" (Ackerman 2007,61). In response to the need for electronic countermeasures to the IED threat the Army has committed to developing a full-scale electronic warfare capability that will be distributed throughout the entire force. This capability has already achieved a measure of success in Iraq and Afghanistan, and now is tailoring its effort to interoperate effectively in a joint environment. The Army stood up an EW (Electronic Warfare) division under the Army G-3 staff. The Army has placed responsibility for EW integration with fires personnel. Ackerman argues that early EW efforts against IEDs were based on a brute-force attack against the entire frequency spectrum as opposed to actions targeted against specific

threats (Ackerman 2007). These early systems were not designed for crowded urban environments with rampant civilian radio frequency systems. These systems often interfered with friendly frequencies, both civilian and military. This interference has been known to affect satellite, FM, and cell phone systems. Military systems adversely affected included global positioning systems (GPS) and communication systems. The communication systems used by Iraq emergency responders, such as Red Crescent ambulances were also disabled. Newer systems have resolved the interference issues and can counter IEDs more effectively while maintaining communications. Interoperability issues with other services EW activities continue to exist.

"Hidden Enemies: Adaptive Foe Thwarts Counter-IED Efforts," by Stew Magnuson is an article that describes some of these interoperability issues (Magnuson 2006). There have been numerous incidents where commanders must turn off their jammer to be able to talk on the radio. If a patrol comes under attack, a soldier will open a gap in the jammer's frequency to radio for help. This open gap exposes the unit to attack by insurgents, who are able to use the gap to detonate an IED. The article continues to describe a condition it calls "electronic fratricide," where friendly communications or jammers cause outages detrimental to coalition forces. The article states this condition is getting worse, not better. Around the Baghdad area pilots feel like they are flying with the squelch on because of the static and interference. The article continues stating that there is such a proliferation of electro-communication devices and information technology devices in the battle space that control of EW has run away from the military. As the power and sophistication of jammers increase there is a possibility that they may actually cause an IED to detonate. While this may seem like a positive

effect, consider an IED detonating on an IED makers bench, which is located in a residential complex, or a IED detonating while friendly forces are attempting to defuse it. The insurgents have moved to other methods of triggering IEDs in response to U.S Forces' use of EW. One of these methods is the use of infrared triggers that can be built from commercial garage door openers and burglar alarms, and do not use a radio signal. This has been countered by placing a glow plug in an ammo can, and mounting it on a frame six feet in front of a vehicle. The glow plug creates a heat signature that is detected by the infrared trigger and detonates the IED, in front of the target vehicle.

In "Marines Have New Devices, Goals; Cold War Tactics Adapted" David Axe discusses how Marine aviation supports personnel on the ground in Iraq (Axe 2006). Two-seat Hornet jets were designed to jam enemy radar, but are now being used to jam radio signals that detonate IEDs. Marine aviators are also trading bombs for updated targeting pods, called "Litening," that include TV and infrared cameras, which can help target bombs or enable aircraft crews to look for insurgents, or even spot them emplacing IEDs. Jammers that are aircraft mounted have a much larger range than vehicle mounted jammers. Some of these aircraft mounted jammers can be set to detonate IEDs.

The next counter-IED method this paper will examine is commonly referred to as route clearance, and is usually the responsibility of the engineers. An article by Yochi Dreazen titled "The Bomb Squad," describes a day in the life of a route clearance team operating in Afghanistan (Dreazen 2009). Marine Sergeant Mario Spencer is responsible for the team that operates in a Buffalo mine-protected clearance vehicle, named "Bonecrusher" that patrols along Route 515. The article states that last year IED attacks in Afghanistan increased by 33 percent. The decision to increase troop strength in

Afghanistan will increase the use of roads, and an increase in coalition dependence on route clearance teams. The article discusses how Talaban militants placed 31 IEDs on the route SGT Spencer patrols over a two weeks period. Two IED attacks killed six Afghans and wounded two Canadian soldiers. The route clearance team lives in their 13-foot tall Buffalo, which is built by Force Protection Inc. in South Carolina. The Buffalo is a type of MRAP. It is their home while they are clearing routes. The windows are three inches thick. SGT Spencer tells of a patrol in early January, when they were clearing a route for a convoy of approximately forty vehicles that left Deleram. The mission was expected to take four days. Route clearance involves moving at a speed of 5 to 10 miles an hour, stopping to examine anything that looks slightly suspicious. On this patrol they examined a pile of hay, a mound of dirt, and a Ziploc bag filled with white powder, all proved to be non-threatening. SGT Spencer relates that they never encounter the militants that plant the IEDs, they would like to catch them so they could insure they were not able to plant any more. He also discusses how they never really develop a close relationship with the members of the convoy that they are protecting. One reason may be that despite the engineer's best efforts, IEDs strike the convoy. The members of the convoy seem to hold SGT Spencer's team responsible for their losses (Dreazen 2009).

SGT Spencer continued describing how the next day his team was called to investigate a possible IED. The Buffalo is equipped with a 30 foot arm that has a digging attachment. This is used to investigate possible IEDs. The usual routine is to dig a trench around the possible IED to cut any wires that may be leading to it. Next they begin examining the IED itself, a camera on the arm facilitates this, without exposing the team which remains inside the vehicle. SGT Spencer described how a part of the IED, a

blue jug about the size of a watermelon, got stuck on the digger. He put on his protective vest, walked out to the stuck bomb and tried to yank it free. It required two other members of his team working 15 minutes to free the digger. They placed the blue jug on the ground and called for the bomb-disposal team. It was determined that the blue jug had enough explosives to destroy an armored HMMWV. The bomb-disposal team moved the jug a few hundred yards into the desert and wired it for controlled detonation. The bomb-disposal team allowed SGT Spencer to assist with the detonation by initiating a countdown. When he reached zero, they detonated the jug. SGT Spencer related how he felt much better knowing that they found the IED, instead of the IED finding them, or those in the convoy they were protecting. Shortly after the incident with the blue jug, SGT Spencer returned to his 5 to 10 mile pace, leading the convoy. A truck, for no apparent reason, decided not to wait and passed the Buffalo. The truck encountered an IED so powerful it shook the Buffalo, which was about 20 yards behind it. The truck signaled it was OK and the engineers were surprised, until they identified the truck as an MRAP. A member of SGT Spencer's team, called the MRAP a tough SOB. It was able to continue the mission on its own power.

Two hours after this event, the convoy arrived at its destination, a US patrol base. Their journey was over for the day. SGT Spencer tells how nighttime is usually when militants plant IEDs on route 515. He received a message that a reconnaissance aircraft had spotted two men who appeared to be hiding an IED along the highway, at the same place that the team had located the blue jug. That would be one of the top priorities when the "Bonecrusher" started its patrol the following day.

Michael Silva's article "IEDS: The Obstacle in the Path to Assured mobility" begins by stating that engineers have traditionally been responsible for breaching obstacles and clearing the path for armies to advance (Silva 2007). This is where the term sapper came from, the engineers' ability to clear a path or breach an obstacle. It continues describing how engineer route clearance teams are doing heroic work in assuring mobility for coalition forces in Iraq and Afghanistan. Today's obstacles are IEDs. Engineers use Buffalos, Huskys, RG-31s and other vehicles, as they patrol their assigned routes in an effort to find IEDs before the IEDs find their targets. Once the engineers locate an IED, they turn the mission over to explosive ordnance disposal (EOD) teams, who will detonate the IED. EOD personnel are the best trained soldiers to detonate the IED

Engineers do not have a certifying explosive ordnance course, but this does not mean that they are not trained to deal with explosives. Some question why engineers are not detonating IEDs. The basic tasks in combat engineer training (MOS 21) are to neutralize booby traps, construct firing systems, prime explosives, construct demolition-initiating systems, and identify characteristics of demolition and explosives. These basic skills are developed as engineers rise in rank. Engineer officers training in explosives is more detailed than that of enlisted engineers, culminating in Explosive Ordnance Clearance Agent (EOCA) Course and the Sapper Leader Course, which has live fire demolitions exercises.

There are many tactics, techniques, and procedures for route clearance teams, and many different vehicle configurations used for route clearance patrols. Silva states his purpose is not to discuss the differences, but to focus on the common factors. When a

route clearance team spots a possible IED on an improved road, the patrol comes to a halt. The first action is generally to search for secondary devices, they check for wires or other triggering devices. Then they interrogate the IED using the digger on the mechanical arm on the Buffalo. If the IED is confirmed, then the EOD is called. While they are waiting for EOD to arrive, the engineers are most vulnerable to attack. When EOD arrives, they will most likely send a TALON robot, which they remotely control from inside the protection of their vehicle. The TALON will confirm the engineer assessment using a camera. The TALON will then place an explosive charge on the IED and return to the EOD vehicle. Then EOD will detonate the IED. The last action on the IED site is to collect remnants of the IED, either with the TALON, or when the site is secure, by EOD personnel. The gathering of these remnants is often used to defend the policy of using EOD to detonate the IED. These remnants can be analyzed to identify the IED maker. Silva states that remnants are only gathered in perhaps ten percent of IEDs detonated. Another reason for the use of EOD is due to difficulties engineers have had with IEDs that resulted in injury or death. EOD personnel are limited, so engineers locate IEDs and EOD detonates, and investigates them. Silva states that as of March 2007, this arrangement was being questioned. The skill level of engineers has improved to the point where EOD may not be necessary in all cases. This would lead to more rapid destruction of the IED, and a decreased vulnerability of the route clearance teams.

LTC Keith Landry and CPT Cory Hoeksema authored an article titled "IED Crater Repair in Baghdad" that discusses another engineer contribution to the counter-IED effort (Landry 2006). The article tells the story of the 92nd Engineer Combat Battalion (Heavy) or the "Black Diamonds." The day after they assumed responsibility

for their mission in Baghdad, they deployed an element on a five day mission to repair three significant road craters on a main supply route (MSR). They would end up repairing 105 craters of various sized over the length of their one-year tour. The craters were from detonated IEDs and their repair is a priority because the crater creates a restriction in the MSR, creating a choke point where coalition vehicles can be targeted by IEDs and insurgents repeatedly place IEDs in the same hole, which they will cover over to look like a “normal” road repair.

The first step in crater repair is a deliberate recon, which takes advantage of security by an element of the ground forces and air security that control the area where the crater is located. The ground forces will establish a priority for crater repair. The Black Diamonds will determine what materials will be required to repair the crater. When the materials are available, the ground forces are contacted for an escort, and the Black Diamonds will execute the repair. The equipment that the Black Diamonds bring with them are M1087 palletized load system (PLS) with concrete modules, dump modules, and a flat rack to carry a bobcat and a portable hand tamper. A M916A1 with a M870 lowboy trailer carries a HYEX and a vibe roller for very large repairs. A Buffalo, and M1114s are used to transport engineers to the site, for command and control, and site security. Where possible blast debris is pushed back in the crater and compacted to form a sub-base. Some repairs require the edges of the existing road to be cleaned up, using a jackhammer attachment on the bobcat. Other missions require the vertical construction squad to prepare a formwork when the existing road surface does not encircle the crater. Then a four to six inch reinforced concrete cap is placed over the compacted sub-base and tied into existing asphalt using mechanical anchors. The ground force is responsible

for guarding the site until the concrete is set. The troop carrying vehicles used by the Black Diamonds are armored, but the engineer equipment is not. During their one-year tour two engineers were wounded while conducting crater repairs as a result of insurgent mortar fire. The Black Diamonds have found IEDs in the craters they were to repair; they have found anti-personnel mines on the road shoulder near one of their craters, and have received small arms fire.

MRAP

The next section will examine the MRAP. It will begin by looking at an article by R. M. Ogorkiewicz, titled "New class of armored vehicle emerges to counter mine threat" (Ogorkiewicz 2008). This article talks about the history of the MRAP. The article begins by describing how armored vehicles, typically tanks, have countered mines. During the Second World War, armored vehicles would maneuver around minefields. When this approach was not possible, the minefield would be cleared using flail tanks, mine-clearing rollers, mine ploughs or other devices. The Cold War, with its defensive posture in Europe, did not place priority on designing armored vehicles to counter mines. The development of an armored vehicle designed to counter the mine threat was initiated in response to an asymmetric threat during the 1960s and 1970s. Ogorkiewicz gives three reasons for this development. First, armored vehicles were employed on a smaller scale. Second, few tanks were employed, so the armored vehicles employed had less armor, and were more vulnerable to mines. The third reason is that mines became the weapon of choice for the terrorists or insurgents (Ogorkiewicz 2008).

In March 2007, Jeremiah Cushman, published an article titled "US Military Pushes Blast-Resistant Vehicles" (Cushman 2007). It begins with the statement that, "the

deadliest threat to US troops in Iraq has turned out to be roadside bombs, but there is a truck available with a V-shaped bottom that offers much better protection than armored HMMWVs. Indeed, not a single Marine has died while inside one of these combat trucks" (Cushman 2007). The procurement program divided the MRAPs into three categories. Category one is the smallest, consisting of a six man patrol vehicle, this has also been called the Mine-Resistant Utility Vehicle (MRUV). Category two is larger, designed to carry ten, and capable of missions other than just patrolling, such as an ambulance. Category three is the largest, designed for engineer use for route clearing, anti-IED operations.

The strategy research project titled "*The Mine resistant Ambush Protected Vehicle, A Case Study*" by COL Michael Howitz focuses on the accelerated acquisition process used for the MRAP program. COL Howitz states that the MRAP rapid acquisition is one of the largest material acquisition programs since World War II and provides an example of how the US industrial base is agile. He states two examples of how problems were resolved in a lack of tires and a lack of steel, as support for this agility. This article is helpful in understanding the effort that went into accelerating the procurement process (Howitz 2008).

A report by the U S Government Accountability Office titled "*Rapid Acquisition of Mine Resistant Ambush Protected Vehicles*" dated 15 July 2008, signed by Michael Sullivan, the director of Acquisition and Sourcing Management states that 75 percent of casualties in current combat operations in Iraq and Afghanistan are caused by IEDs. The DOD initiated the MRAP program to mitigate this threat. In May 2007, the Secretary of Defense stated that the MRAP program was the single most important program. The

report states that as of July 2008 $22 billion has been appropriated for more than 15,000 MRAP vehicles, and about 6,600 had actually been fielded. The report examines the acquisition program. The report states that there may be issues for the US Army due to the accelerated acquisition program (Sullivan 2008).

"Mine-Resistant, Ambush-Protected (MRAP) Vehicles: Background and Issues for Congress," by Andrew Feickert discusses the evolving requirement for MRAPs (Feickert 2008). The Buffalo MRAP was originally intended to be used by Army engineer units. The Marine Corps decided in February 2007 to replace all HMMWVs in Iraq with MRAPs while the Army chose to continue to rely on armored HMMWVs. In March 2007, the MRAP requirement grew by 15 percent as the Navy, Air Force, and US Special Operations Command (USSOCOM) added requirements that totaled 7,774 as of 26 March 2007. The article states that in May 2007, the Army began considering replacing all HMMWVs in Iraq with MRAPs because of requests from commanders in the field (Feickert 2008).

The Center for Strategic and Budgetary Assessment published a report titled "*Of IEDs and MRAPs: Force Protection in Complex Irregular Operations*" by Andrew Krepinevich and Dakota Wood. This report begins with a statement that simple solutions to complex problems seem attractive but are almost always wrong. The report goes on to state that political and military leaders are struggling with how much to invest in the MRAP, without undermining the ability of the force to conduct its current mission, and the forces' ability to be effective across the full spectrum of conflict. The report does not seek to determine what mix of armored vehicles are needed, but will provide information for others to draw their own conclusions (Wood 2008).

"US Prepares Vehicle Road Maps – Studies May Retire M113s, Limit MRAPs, Prolong Humvees," by Kris Osborn" states that the Pentagon's various vehicle programs are headed for a collision (Osborn 2008d). The article discusses a rush of orders for MRAPs, continued purchases of Humvees, and plans to buy the Joint Light Tactical Vehicle and the Future Combat Systems. The resolution is still being determined but the initial response is likely to include retiring the M113, a 10.5 ton tracked, armored personnel carrier that has been in service since 1960. Second, the MRAP will become less ever-present and be restricted to specialized roles. Third, the Humvee isn't going away. The article continues stating that the MRAP, weighing 24 tons, has proven capable of defeating roadside bombs, but are difficult to air load and are not able to move off improved roads. It is likely they will be used for specialized tasks such as clearing routes and disposing of ordnance. Some MRAPs are being equipped to function as command and control vehicles. Some MRAPs will likely be stored in pre-positioned equipment stockpiles.

A USA Today article by Tom Vanden Brook titled "Iraq IED Deaths Down 90 percent in a Year," begins with the statement that roadside bomb attacks and fatalities in Iraq are down by almost 90 percent over the last year, according to Pentagon records (Brook 2008). In May 2008, eleven US troops were killed by IEDs, compared with 92 in May 2007. The article states several reasons for this drop. The first is the MRAP, almost 7,000 were rushed to Iraq during this year. "MRAPs have taken many hits that would have killed soldiers," stated Adm. Michael Mullen, chairman of the Joint Chiefs of Staff (Brook 2008). The second reason is Iraq security forces, providing intelligence to find IEDs and those that make and emplace them. Next is improved surveillance from fixed

security cameras and UAVs. The use of MRAPs has caused the insurgents to use larger IEDs, which provide US forces a better chance of apprehending those that make and emplace IEDs. The article concludes that the IED may have been defeated by the MRAP, but it is not going away.

"10,000th Life-Saving MRAP Fielded" states that on 22 February 2009, the US military fielded its 10,000th Mine-Resistant Ambush-Protected Vehicle from Camp Liberty, in Iraq (Multi-National Corps – Iraq Release 2009). The article states that the first MRAP, not assigned to an engineer unit, was fielded in April 2007, and since then 11,700 have been fielded between Iraq and Afghanistan. Training of more than 22,000 personnel was included in the fielding. The article states that MRAPs have been adapted with upgraded armor, better suspension, improved seats, safety harnesses, gunner's restraints, and improved night driving capability. The MRAPs have maintained a 95 percent operational readiness rate.

"Lighter MRAPs in the Works" by Kris Osborn begins by stating that the final batch of MRAP vehicles purchased by the Pentagon may be several tons lighter and a few feet shorter (Osborn 2008b). Today's MRAPs are about 12 to 14 feet long and weigh from 15 to 22 tons. The article states that field commanders in Afghanistan have been asking for tougher, more mobile MRAPs. A lighter MRAP will be easier to transport and increases the vehicle's ability to handle different kinds of terrain.

"Smaller, Lighter MRAPs Headed to Afghanistan" by William McMcheal states that the Pentagon is speeding deliveries of armored vehicles to Afghanistan to protect troops against roadside bombs, smaller, lighter versions of MRAPs (McMichael 2008). Navistar Defense will begin building and fielding 822 new, lighter MRAPs in November.

There are now 1,122 MRAPs deployed in Afghanistan and 9,341 deployed in Iraq. The Army does not have plans to move any MRAPs from Iraq to Afghanistan. All MRAP deliveries to Afghanistan are by air, since the overland routes are not secure.

"DOD to Buy Interim Vehicle" by Kris Osborn states that the US Army is planning to rapidly develop and buy a fleet of 7 to 10 ton vehicles to counter increasingly frequent roadside bombs in Afghanistan, yet are more mobile than current MRAPs (Osborn 2008a). The US Army is calling these vehicles "interim" vehicles, and is planning to purchase 2,000 at first and then later up to 5,000. These are to meet Army needs until the Joint Light Tactical Vehicle (JLTV) can be fielded around 2013.

"Major General Scott West, US Army's TACOM Life Cycle Management Command Chief" by Kris Osborn discusses the future of the MRAP (Osborn 2008c). MG West is asked the question: "What about the need for smaller, more mobile MRAPs in Afghanistan?" MG West's answer is that the requirements sound strikingly like the JLTV. He continues that the Army is aware of the need for a smaller variant of the MRAP as a bridge to JLTV. He also states that it is irresponsible to describe the MRAPs as a family of vehicles. A family of vehicles is defined by multi-mission capabilities and similar characteristics, and near-perfect match on components and sustainability. MG West states that this is not the case with MRAP; they have different engines, different transmissions, and different air-conditioners. He continues "At some point in time, we will keep the MRAP. It is part of our long-term strategy, and it can't afford to look like five different manufacturers."

This chapter has looked at professional writings and publications that discuss the IED threat, non-MRAP countermeasures, and the MRAP. It has been discussed how

insurgents are constantly adapting IEDs. US forces are adapting to these changes. These areas are constantly changing and articles are being published with current information. The literature review has used professional writings and publications available through May 20, 2009. All information contained in this literature review is unclassified, open sourced, and readily available to the public. The following chapter will discuss how the information in the literature review will be used to answer the research question of the MRAP meeting the US Army's need as the primary method of protecting troops from the IED threat.

CHAPTER 3

RESEARCH METHODOLOGY

The research methodology for this paper will include information discussed in the literature review, information discussed in a telephone interview with the MRAP program manager (MRAP PM) on 21 January 2009, and information discussed in blogs with maintenance warrant officers who are in Iraq responsible for maintaining MRAP vehicles. The research methodology will be identified for each question. The research question: does the MRAP meet the US Army's needs as the primary method of protecting troops from IEDs, will be addressed by looking at the three secondary questions. The first secondary question will look at the IED threat, to understand the threat and, identify the requirements to protect troops from this threat. These requirements will focus on protection, rapid fielding, and supportability. Information from the literature review will be used to answer this question. The second secondary question will look at non-MRAP countermeasures used by the US Army, to understand their capabilities and limitations. These capabilities and limitations will be compared with the requirements to protect troops identified in the examination of the IED threat. Information from the literature review will be the primary source of information to answer this question. The third secondary question that this paper will look at is the MRAP, to determine capabilities and limitations. Examining the history of the MRAP and the acquisition method, will assist in this determination. Comparing the requirements and capabilities will address the suitability of the MRAP to meet the Army's needs. The primary information source used to answer this question will be an interview with the MRAP PM and the blogs of senior

warrant officers who currently are responsible for maintaining MRAPs in Iraq. Information from the literature review will also be used.

Defining the MRAP will include examination of the history of the MRAP using information provided in the literature review. This definition will also include examination of the MRAP acquisition process. The Army's need to counter the IED threat was immediate. This required MRAPs to be placed into use expeditiously. The MRAP PM utilized five manufacturers to accomplish this. The methodology to examine this will be the interviews with the MRAP PM. The other implications of the expeditious fielding include supportability. The question of supportability includes fuel consumption, availability of repair parts, and both operator and mechanic training. These implications must be addressed to determine if the MRAP meets the US Army's needs to protect troops from the IED threat. If the MRAP cannot be supported, it becomes a stationary steel bunker, and is not protecting troops. If the troops are not trained to operate and sustain the MRAP, it becomes ineffective as well. Both sustainment and training are components of the MRAP description and will be examined using both the interviews with the MRAP PM and warrant officers and the literature review. The MRAP PM acknowledged that they accepted risk in decreased supportability in their efforts to expedite fielding of the MRAP.

The reasons the requirements and capabilities methodology has been used is that this is a materiel solution. The US Army's approach to materiel problems is to first identify the requirements in a given situation. The next step is to identify the capabilities of the resources that are currently available. If the capabilities meet or exceed the requirements then a plan is developed to use available resources to meet the

requirements. When the requirements exceed the capabilities of available resources than additional resources are required. If it is found that the non-MRAP countermeasures did not have the capability of protecting troops from the IED threat, then the additional resource of the MRAP is required.

CHAPTER 4

ANALYSIS

The purpose of this research is to answer the question: Is the MRAP the best method of protecting US troops from the IED threat? This study has looked at how the US Army has suffered many casualties from Improvised Explosive Device, (IED) attacks in their operations in Iraq and Afghanistan. The primary vehicle used to transport troops, the High Mobility Multipurpose Wheeled Vehicle, (HMMWV) has no IED protection. The US Army has utilized many different approaches to protect troops and counter the IED threat. The first approach used was to add additional protection to the HMMWV, using sand bags and then additional armor plate, initially this armor plate was fabricated in the field, later factory produced kits were utilized. Improved body armor was issued to deploying troops. These proved ineffective. The US Army next provided training to all forces deploying on lessons learned on how to avoid IED strikes and how to react when attacked by an IED. The US Army also used electronic and thermal devices to interfere with the triggering mechanism used to detonate the IEDs. The US Army also used experts such as engineers to clear routes and repair roads. The US Army replaced all unarmored HMMWVs, which had armor kits applied, with up-armored HMMWVs, which were designed to provide protection from small arms fire, but not designed to counter the IED threat. US Army troops were still dying from IEDs. Another solution was required. The US Army turned to the MRAP after analyzing the IED threat and the non-MRAP countermeasures.

The results of this study provides US Army personnel information about the IED threat, non-MRAP IED countermeasures and, the history and capabilities of the MRAP.

It also provides decision makers with an understanding of the needs of the US Army that have resulted in the MRAP program, as well as some of the effects that the MRAP program has had on the US Army.

This chapter is organized by looking at the question of the IED threat first, then the question of non-MRAP countermeasures and finally the question of the MRAP. Examination of the IED threat assists in establishing requirements for adequate troop protection. IEDs come in many sizes and configurations so these requirements are descriptive in nature. They describe the range of the IED threat as opposed to specifying a definitive requirement. The IED threat has evolved as countermeasures have been employed against it. This evolution of the IED threat requires an evolution in the requirements to protect troops from that threat. The threat is changing and the solution must be able to adapt to these changes.

Non-MRAP countermeasures will be examined to see if the capabilities they have are able to meet the requirements of the IED threat. If it can be shown that the non-MRAP countermeasures were not successful in protecting troops from the IED threat, then there is support for the MRAP materiel solution. It must be noted that many of the non-MRAP countermeasures, such as IED training, radio jamming, and clearing routes, are employed in conjunction with the MRAP to protect troops. The data examined in this paper will show that the non-MRAP methods alone do not have the capability of protecting troops from the IED threat. It is recognized that a combined approach is optimal, MRAP with other non-MRAP countermeasures. The question of this paper is the significance of the MRAP, does it provide the best level of protection available to protect troops from the IED threat?

The last section of this analysis will be to examine the MRAP. This will begin with the history of the MRAP, and finish with the expected future of the MRAP in the US Army. This analysis will develop a general capability of the MRAP, which can be compared with the requirement identified in the discussion of the IED threat. This comparison of requirement and capability will result in the answer to the question of the MRAPs ability to best protect troops from the IED threat.

IED Threat

IED's have been a serious threat to American troops during operations in Iraq. An IED can be disguised to look like any object and may have complicated triggers, with a design only limited by the maker's imagination and expertise. The main charge is normally military ordnance, and the most common trigger is by remote control or wire by command from a person, or command detonated. IEDs are often hidden in garbage on the side of a road. There are often multiple IEDs placed together or even fake IEDs placed to draw responders into range of an IED (Headquarters, Department of the Army 2005).

An article by John Ringquist titled "Challenger in Military Engineer Operations: Ten Soldier's Experience in Iraq 2003-2007," discusses the IED threat. This article states that it became common knowledge to expect IEDs where sand bags or stacked trash bags were observed on the side of a road. It goes on to state that before the collapse of the Saddam Hussein regime, there were no plans for engineer units to deal with IEDs. Captain Walker, then a member of the 70th Engineer Battalion, stated that "Training for IEDs wasn't considered because they weren't a recognized threat" (Ringquist 2007). The article continues with the statement that by 2004 many units were conducting IED

identification classes. This change in engineer mission was also noted by Captain Thorp, who served with the 3rd Infantry Division. He stated that "the engineer effort's focus in 2003 was on clearing minefields, UXO [unexploded ordinance], creating lanes in obstacles and mobility operations. I (Captain Thorp) don't think anyone expected the IED threat we now have" (Ringquist 2007).

The average IED is described as composed of old Saddam era military ordnance, for example, artillery shells that were stored in caches throughout the country. A major mission of the engineers was to destroy these caches to decrease their availability for IEDs. The engineers also encountered a second type of IED identified as an EFP or Explosive Formed Penetrator. The IED is a blast weapon that creates shrapnel and concussion to kill or wound in all directions but the article describes an EFP as firing a molten spray of metal in a specific, limited direction. He states that EFPs became a threat in 2006 (Ringquist 2007).

One definition of an IED is a bomb or mine made from homemade explosives. The makeshift nature of the IED may lead some to believe that they are simple. This is not true. "Urban Warfare's Most Sinister Weapon" by Andy Oppenheimer compares the IEDs in Iraq to those produced by the Irish Republican Army (IRA) in Ireland. Highly trained operatives, who use military-grade ammunition, and state-of-the-art timing or triggering mechanisms, build most IEDs. The degree of complexity of the device is limited only by the bomb-makers abilities and available material. Most IEDs incorporate military, commercial, or homemade explosives, an initiation system or fuse, explosive fill, detonator, power supply for the detonator, and a container. They could also incorporate toxic chemicals, or flammable materials such as sugar mixed with gasoline.

The military explosive may be in the form of a hand grenade, land mine, mortar round, large artillery shell, or even an airplane bomb (Oppenheimer 2006).

IEDs placed in vehicles are called a vehicle Borne IED (VBIED). VBIEDs tend to have larger amounts of explosives and are normally triggered by the driver, who is willing to die in the explosion. Another delivery system is the victim-operated IED (VOIED) commonly called a suicide vest. There are many methods of triggering a roadside IED with a radio signal. These radio triggered IEDs are called radio-controlled IED (RCIED). The RCIED can be triggered by cell phones, remotes, car alarms, key fobs, doorbells, two-way radios, and pagers. The person triggering the IED, or command detonating it, usually requires a line of sight or an unobstructed view of both the IED and the approaching target. This is required to trigger the device when the target person or vehicle is in range of the IED. Radio controlled IEDs allow the person triggering the device to maintain a greater distance from the IED than trigger that is wired to the IED. Another triggering device involves pressure plates separated by a spring. The weight of a vehicle or person on top of the plates forces them together, and the IED is triggered. No person is required to trigger this type of IED as the victim activates it. Another victim activated system uses infrared beams that are triggered by engine heat (Oppenheimer, 2006).

IEDs have been disguised as manhole covers, or encased in concrete or plaster in the shape of a curb or other items that belong on the road. They have been placed in Meals Ready to Eat (MRE) boxes, donkey carts, plastic bottles, soda bottles, and even dead animals. They have also been placed in tunnels dug under the road . (Oppenheimer 2006).

The typical IED is described in “Conventional Ammunition Surplus” by Adrian Wilkinson, James Bevan, and Ian Biddle, as containing a main charge, an initiator, a firing switch, a safety and arming switch, and a container. In autumn, 2003, United States military commanders estimated that Iraq military sites contained between 600,000 and 1,000,000 tons of ammunition and explosives in over 130 ammunition storage sites. This is in addition to 10,000 cache sites discovered later in 2004. In November 2004, the United States Defense Intelligence Agency reported that the majority of explosives used in IEDs came from pilfered Iraqi ammunition stockpiles. In December 2003, there were only 250,000 tons partially secured. Some sources report that insurgents obtained used these unsecured munitions to fabricate IEDs. (Bevan 2009).

Some IEDs have only a single device and are placed quickly; while others are more complex using multiple linked main charges or even devices that contain large charges removed from multiple projectiles. Most roadside IEDs are remotely initiated and have a fusion of civilian components and military ammunition. Often a “firing pack” is used to help detonate the military ammunition, which consists of a wireless device, like a mobile phone, a battery pack, a safe-to-arming switch, and timer. An electrical detonator is usually placed in a small quantity of booster explosive. This ‘firing pack’ is placed in or next to the main explosive charge or military ammunition.

Explosively Formed Projectile (EFP) are often confused with traditional high-explosive anti-tank (HEAT) shaped charges. HEAT shaped charges consist of a metallic cone, while the EFP uses a metallic disc, this difference results in different target effects. HEAT rounds produce a molten jet of metal that penetrates the target with a hydro-dynamic effect; the EFP produces a fragment that uses kinetic energy as an attack

mechanism. At short range the EFP has a limited HEAT effect, which is commonly called a 'dirty' HEAT effect. An EFP can penetrate a thickness of armor equal to the diameter of the charge, where a HEAT round will penetrate a thickness of armor six or more times the diameter of the charge. The EFP has an advantage as a standoff weapon, with a range significantly greater than the HEAT round. EFPs are constructed using metal piping and copper sheeting. The pipe is filled with high explosive and capped with a concave steel or copper liner. The explosive shapes and compresses the liner into a hot metallic fragment, which can penetrate thick armor (Bevan 2009).

As armored vehicles were developed with countermeasures to protect them from EFPs, insurgents turned to extremely large quantities of explosives, large enough to throw the entire vehicle into the air. IEDs this large are used in less than 10 percent of IED strikes and take a relatively long time to emplace (Bevan 2009).

"Insurgents adapt to US defenses faster than military adjusts to IEDs," written by Peter Eisler discusses the experiences of Army Captain Patrick Murphy, who arrived in Iraq in June 2003 and left in 2004. Captain Murphy stated that the placement of IEDs, the way they were triggered, and the explosives employed, were constantly changing. The major components used to make IEDs such as artillery shells, and explosives like Trinitrotoluene (TNT) or C-4 were looted from Iraq military ammunition caches that were not secured. A Government Office of Accountability, (GOA), report cited by Eisler states that "not securing these conventional munitions storage sites has been costly, the looted materials have given insurgents ammunition to construct IEDs . . . and maintain the level of violence" (Eisler 2007, A11). Early IEDs were relatively small and simple, often a 155mm or 152mm artillery shell hidden in a wall or embankment along the road.

Insurgents would run wire from the IED to a handheld trigger, which they would activate from a hiding place. The hiding place was chosen so they could observe both the IED and the approaching target. The article continues to describe how US troops figured out how to detect these early IEDs by spotting the wires or a suspicious character, so insurgents began using remote triggers such as car key fobs, garage door openers, and cell phones to trigger the IED from greater distances. Insurgents also began to use more powerful explosives, either combining multiple shells in one large charge, or using multiple charges connected or "daisy chained." One technique developed would be to detonate one smaller IED to draw a crowd of first responders. Then a second IED, or IEDs, would be detonated. In early 2004, insurgents began to bury IEDs so that they would attack the bottom of targeted vehicles where there was no armor protection. The insurgents also changed the triggers, from radio-controlled devices (that were susceptible to electronic jamming), to hard-wired devices, or switched to pressure plates that triggered the IED when the vehicle rolled over them. One version was referred to as "baking trays" which contained C-4 explosives sandwiched between two metal plates, which exploded when compressed by a vehicle. The next development in the IED, discussed in the article, is the use of EFPs. The EFP was able to penetrate the armor of all the vehicles the US Army was using in Iraq at that time. Insurgents have adapted to each counter-measure employed. Insurgents have adapted better than the US forces have. (Eisler 2007).

The Center for Army Lessons Learned established an "IED taxonomy" that describes three major categories of IEDs: vehicle borne IEDs, improvised grenades, and improvised mines. Improvised mines are further divided into contact fused, delay, and

command detonated. Command detonated is further divided into mechanical, such as a pull firing device, radio controlled and hardwired. Radio controlled IED (RCIED) initiators include the car alarm keyless entry system, which is the most commonly used RCIED. When using this type of device the trigger person carries an ordinary keyless entry fob. The car alarm component is removed from the car, and attached to the IED detonator and a 12-volt battery. The effective range of these devices is 100 to 150 meters. Another common, everyday system IED makers have adopted to use is the wireless doorbell system. The trigger person carries the doorbell transmitter, and the doorbell chime assembly is connected to the IED detonator. The range on these devices is more limited than the key fob device. A third common, everyday system used to trigger IEDs is the cordless phone. One method is employed is for the base station to be used as the triggering device, and the handset to be attached to the IED. When the trigger person activates the "page" function, the handset activates the detonator for the IED. The range on the cordless phone system can be as much as the key fob or even greater. Radio transmitters for toy models which have greater ranges have also been used. Common two-way radios have also been used in combination with a homemade decoder circuit board that converts low voltage from the two-way radio speaker into enough voltage to detonate the IED. The advantages of the two-way radio system is the large range of frequencies, and the extended range of up to 5 kilometers (CGSC Staff Group 2006).

IED terrain analysis looks at the location where the IEDs are placed, and includes: obstacles, avenues of approach, key terrain, key indicators, observation and fields of fire, and cover and concealment. Obstacles are the first component, it addresses how IEDs are often emplaced in areas where natural and manmade terrain features canalize movement,

restricting dismounted movement perpendicular to the IED. This may be in the form of canals or culverts. These obstacles slow US forces' reaction and allow for the observer or trigger team to get away. Obstacles may also be placed on the road to slow or canalize the target vehicle and force them into the IED kill zone. Avenues of approach is next, it addresses how IEDs will be set where approaches are limited. Key terrain and key indicators are next and they address how terrain features or other man made features, such as telephone posts, are used to gauge the speed of the target and facilitate detonating the IED when the target is in the kill zone. Key indicators are items that may indicate an IED is present, such as rock piles, trash and debris, or wires. Observation and fields of fire address how the trigger person will be located where they have a clear line of sight of both the kill zone and the approaching target. Cover and concealment is the last factor in the IED terrain analysis. It addresses how some IED teams have one section observing the kill zone and target, while another team will detonate the IED. The observers may have nothing suspicious other than a cell phone. They place a call to the detonating team, who is hidden from the kill zone, but in close proximity to it. When they receive the signal call, they detonate the IED (CGSC Staff Group 2006).

Elements of an IED team can include over thirty members. The team is divided into various cells or groups that have no contact with the other cells, but use "mules" or individuals with no knowledge of the IED activity, to transport IEDs or components between cells. The decision cell directs the operation, contains a master bomber and is responsible for target selection, internal security and recruiting. The master bomber will train members of the bomb making cell, but is not actually in the construction of the IED. IED components are stored sometimes together, sometimes separately, and will be

transported to the bomb making cell by a mule. After the IED is fabricated a second mule will transport the IED to either a cache, where it will be stored until needed, or directly to an execution support cell. The trigger for the IED will be transported by a third mule to the trigger cell. The execution support cell will recon the IED site, prepare the site and then place the IED. There may also be a cell to record the IED detonation. The security cell is responsible for protecting the organization, both from external and internal threats, such as one cell member working outside their cell. The trigger cell may also include an observer cell, to allow the trigger person to remain hidden. Eliminating one part of this organization will not stop the IEDs. Another cell, the recruiting cell, will just find replacements and the operation will continue (CGSC Staff Group 2006).

IEDs are an anonymous weapon of surprise, with little warning. The targets of the IED attack are not readily able to identify their attacker. The combined effect of these factors on the target: helplessness, surprise, calm before chaos, indiscriminate effect, collateral damage, and anonymity of the attacker contribute to tactical anxiety. IEDs gain strategic power as they are covered by the news media. Insurgents have exploited this by recording their attacks and publishing them on the Internet or releasing them to the media. Insurgents modified their attacks with IEDs faster than US forces could adapt (Bokrl 2007).

Insurgents seized the initiative by choosing the time and place of their IED attacks. The vast majority occurred a short distance from FOBs. US forces countered with Explosive Ordnance Disposal (EOD) teams. Insurgents countered by targeting these teams. US forces countered by developing Counter Explosive Exploitation Cell (CEXC), which served as a consolidation point for discovered or neutralized IEDs and analysis

that could be used to develop trends, technical information, and identify unique bomb-maker signatures (Bokrl 2007).

This IED threat is responsible for 1,826 deaths in Iraq according to the web site icasualties.org (icasualties.org 2009). Some of the common attributes of the IEDs described include the use of military munitions for the explosive charge and an improvised triggering device based on commonly available commercial components. The explosive charge is employed in a manner that uses the blast effect, or shock wave, to attack the target. This blast effect is not focused in any direction, and significantly decreases with distance. The destructive force that this blast effect possesses is called over pressure, and is defined in terms of pounds per square inch. An example of this would be the force that a 120 MM mortar round which may contain ten pounds of explosive would have. The over pressure of this may be 5 pounds per square inch at a range of three feet. When applied to a four-by-six feet flat bottom of a HMMWV a total of 17,000 pounds which is calculated by multiplying the number of square inches of the flat surface by the pounds per square inch blast effect. Another example of this is the sail on a sailboat. If the sail is down, even in a strong wind there is little effect on the boat. However, when the sail is deployed, even the smallest wind has an effect on the boat. This blast effect may be enough to completely lift the target vehicle off the ground. Injury occurs from the rapid acceleration of the vehicle into the air and deceleration when the vehicle hits the ground. With a big enough charge, the blast effect can be strong enough to even lift a vehicle as heavy as an Abrams Main Battle tank weighing over 135,000 pounds.

The second component of the IED is the triggering device. This component is critical for the IED to be able to detonate when the target is within the effective range of the blast effect of the main charge. This is compounded when the target may be traveling at a speed of over 45 miles per hour. Forty-five miles per hour is equal to 66 feet per second, and the HMMWV is 15 feet long. The average HMMWV travels in a convoy with four other vehicles with a two vehicle gap between each vehicle. The entire convoy may be only 180 feet long giving the insurgent less than three seconds to trigger the IED while the convoy is in range. If the IED is triggered within this three seconds, there is a one and three chance it will detonate under a vehicle and not between vehicles. A common method used by insurgents to better their odds of success is to place obstacles in the path of the target to slow it down or even stop it within the effective range of the blast effect.

The insurgents have adapted their use of the IED to counter measures employed by US forces. The next section will discuss US forces non-MRAP countermeasures. What must be noted in the description of the IED is the fact that insurgents have developed the skill to effectively employ a simple weapon. This skill includes the ability to procure the IED components, fabricate the IED, emplace the IED, and trigger it within range of the target. Insurgents have proven highly adaptable. Insurgents have also displayed a high degree of dedication in their employment of IEDs. The author has witnessed suicide bombers sacrifice themselves to destroy a Stryker tire.

There is also a psychological impact of IED strikes. The US Army trains for a linear war, with the enemy at the front lines, and the non-combat units operating safely in the rear area. Insurgents have used IED attacks to change this. Iraq has no safe rear

areas. Every convoy that travels on the roads in Iraq must be prepared for combat. The other psychological impact is the lack of an identifiable enemy. Often the IED detonates, US troops are injured, and no insurgent is identifiable. There is no target to retaliate against. The insurgents seek to attack the morale of US forces. The insurgents use mass media outlets to broadcast their successes. This use is an attack against the morale of the US population, and through them the US government. There is also a demonstration of their abilities to the world population.

The IED threat includes many components. The physical component damages US forces personnel and equipment. The psychological component damages the morale of US forces, the support of the American people and world opinion. Insurgents attacked soft targets in US forces. Now that US forces have employed MRAPs, insurgents have adapted by shifting their attacks to Iraq civilian soft targets. The MRAP has protected US troops, but it has not defeated the IED threat.

Non-MRAP Countermeasures

The US forces non-MRAP IED countermeasures have progressed significantly. Two events assisted in raising the priority of these efforts. The first was the capture of elements of the 507th Maintenance Company due to fatigue, bad communications, and other difficulties according to a US Army investigation (Jelinek 2003). No IEDs were involved in the attack on the 507th, this event raised awareness that troops were vulnerable in unarmored logistic support vehicles in combat. The second was then Secretary of Defense Donald Rumsfeld’s response to SPC Thomas Wilson’s question in December 2004 in Kuwait. The question asked why soldiers had to dig through local landfills for scrap metal to protect their convoy trucks because their vehicles were not

armored. Secretary Rumsfeld's response was that "You go to war with the army you have, not the army you want or wish to have as a later time" (Schmitt 2004, A04). Fourteen soldiers died in the month of December 2004 from IEDs (icasualties.org 2009). The MRAP PM stated that the US Army used methods that it had used in the past to counter the IED threat, and did not turn to the MRAP until these other approaches proved ineffective.

The first approach is that described in SPC Wilson's question. Existing vehicles were modified with locally fabricated steel plate. The Army supported this approach and tasked maintenance companies to assist in the process, standardizing armor kits. An armor kit fabricated in the US and installed locally followed. Included in this approach is an effort to improve personal body armor worn by US forces. This improved body armor added a layer of protection from both IED attacks and small arms attacks. Adding protection to existing vehicles was effective against small arms attacks, but ineffective against IED attacks. The flat bottom of US Army vehicles, even if it was armored, was vulnerable to the IEDs blast attack. Insurgents reacted to this countermeasure by using larger charges in their IEDs.

The second approach was increased training. US forces deploying to Iraq received training in Kuwait on how to react to an IED attack, how to identify IEDs, and how to effectively counter the IED threat. The effective counter included focusing on the insurgents that were fabricating and emplacing the IEDs, convoy security, and gaining the trust of the Iraq people. The focus on IED makers encouraged a "designed" approach which encouraged recording IED attacks to develop patterns. These patterns would be studied, and components would be analyzed to identify their source, and enable

prediction of future attacks. Convoy security included efforts to increase convoy speeds, change the time and route that routine convoys used, insure that convoys had adequate weapons to defend themselves, adequate communication resources, and adequate medical personnel. Gaining the trust of the Iraq people would result in information tips about locations of IEDs and IED makers. Insurgents responded to this approach by adding security to their IED cells, and developing methods to more accurately target US vehicles.

The next approach was to disrupt the triggering command. As insurgent turned to radio based triggers to more accurately target US vehicles, US forces developed technology to jam radio signals. Insurgents adapted by using alternate frequencies. The jamming devices also interfere with US forces communications. The continued developments to this technology have increased the bandwidth of the jamming capability and limited the interference with friendly communications. Insurgents reacted by using the heat signature of the vehicles engine as a trigger. US forces reacted by placing a heat source six feet in front of their vehicles. Insurgents reacted by using alternate triggering methods, such as a hard wire. This method is easier to detect and more likely to expose the insurgent triggering the IED. These jamming devices are currently emplaced on MRAPs, and are effective against radio triggered IEDs, but has no effect on other triggering methods.

The final approach is to employ experts against the IED threat. The most common example of this approach is the use of engineer units for route clearance and route repair. Engineers were authorized early versions of the MRAP for their route clearance mission. These route clearance teams became experts at locating IEDs along

their assigned route. When an IED was located an EOD team would be utilized to destroy it. EOD teams also collected fragments of the IED to assist in locating the makers of the IED. Route repair is effective in countering the IED threat because insurgents tend to place IEDs in the same spot. A repaired road is an IED free road. Insurgents have responded to the use of engineers by emplacing IEDs designed to target them. False IEDs have been emplaced to draw their attention, and other IEDs emplaced along the probable route of the engineer responder. Insurgents have even infiltrated road repair crews to emplace IEDs in the repair.

These approaches have significantly decreased the effectiveness of the IED threat. However, the use of existing US Army flat-bottomed vehicles, even with added armor protection leaves troops vulnerable to IED attack. The most effective countermeasure is a vehicle designed to withstand an IED attack, with a V-shaped bottom, to deflect the blast and not absorb it.

MRAP

The answer to the question of the capabilities of the MRAP will first look at its history in an effort to understand how and why it was developed. Armored vehicles, typically tanks, have countered mines during the Second World War. Their primary countermeasure was to maneuver around minefields. When this approach was not possible, the minefield would be cleared using flail tanks, mine-clearing rollers, mine ploughs or other devices. The Cold War, with its defensive posture in Europe, did not place priority on designing armored vehicles to counter mines. The development of an armored vehicle designed to counter the mine threat was initiated in response to an asymmetric threat during the 1960s and 1970s. “New class of armored vehicle emerges

to counter mine threat" by R. M. Ogorkiewiez gives three reasons for this development. First, armored vehicles were employed on a smaller scale. Second, few tanks were employed, so the armored vehicles employed had less armor, and were more vulnerable to mines. The third reason is that mines became the weapon of choice for the terrorists or insurgents. These reasons made it a priority to improve the armored vehicles' ability to withstand an attack by a land mine. The article states that of all the casualties suffered by US personnel in armored vehicles, 69 percent were caused by land mines, this is compared with 23 percent during the final stages of the Second World War. Countermeasures that were employed during the Vietnam conflict were limited to the addition of steel plates under the aluminum hulls of M113 personnel carriers and M551 light tanks. There is also evidence of adding armor to cargo trucks to counter the ambush threat. United Kingdom forces encountered land mines in the 1960s, which caused a number of casualties in armored vehicles. There was no development in vehicle design in response to these attacks. Soviets armored vehicles suffered serious losses in Afghanistan from land mines placed by the Mujahedeen. Again, there were no countermeasures beyond the addition of armor plates to Soviet tanks (Ogorkiewiez 2008).

The first developments in armored vehicles designed specifically to counter the land mine threat took place during the 1972-1980 war in Rhodesia (now called Zimbabwe). The security forces in Rhodesia operated in unarmored vehicles, such as Land Rovers, at the beginning of the war. They suffered serious losses from land mine attacks. Ogorkiewiez quotes statistics by Dr. Vermon Joynt, a South African mine expert, that for every anti-tank land mine detonated an average of one person was killed and two were injured. The article states that there are no comparable statistics available

for coalition operations in Afghanistan and Iraq, but given that the HMMWV and Land Rover have similar vulnerabilities to land mines, the author would expect similar statistics. South Africa began to develop the MRV (mine resistant vehicle) as the conflict in Rhodesia began to spread into their country. The first MRV developed was called the Buffel. It was a six ton, 4X4 armored personnel carrier with an open-top steel hull that had a V-shaped blast-deflecting bottom. This V-shaped hull is an identifying feature of the MRAP today. The South African Army acquired about 1,400 Buffels. The rate of fatalities was reduced to one for every 21 anti-tank land mine detonations. The Buffel was followed by the Casspir, which weighed eleven tons and had a V-shaped hull with an integral monocoque construction, a construction technique that supports the structural load by using an object's external skin. There are 54 recorded anti-tank land mine detonations against the Casspir without one fatality. The Casspir was able to withstand an attack by three stacked anti-tank mines, with 21 kilogram of TNT, or about 47 pounds. There were over 2,000 Casspirs produced, and they have been used by organizations outside South Africa for mine clearing operations (Ogorkiewiez 2008).

The next development was the 6.8 ton Mamba, manufactured in South Africa. Like the Casspir, the Mamba had a monocoque hull with a V bottom. It was able to withstand an attack by two stacked anti-tank land mines, or 14 kilogram of TNT or 31 pounds. It was also designed to withstand a side blast of 30 kilogram of TNT or 67 pounds. The conflict in South Africa was moving from the countryside into an urban environment, where side blasts were considered a threat. The Mamba was also designed with large bulletproof side windows, to improve situational awareness of the crew. In addition there were stowage containers on the outside of the vehicle to make more room

for the crew in the vehicle. Over 700 Mambas were produced, and became the standard APC of the South African National Defense Force (Ogorkiewiez 2008).

The next threat from land mines was in the mid-1990s in the Balkans. The UN peacekeepers there were unsuccessful in countering the threat with conventional armored vehicles. This lead to an interest in the South African MRVs, and in 1996 the British Army purchased six Mambas for use in Bosnia. The US Army purchased five RG-31s, which are very similar to the Mamba. The Canadian Army also purchased some RG-31s (Ogorkiewiez 2008).

The next development in MRV design was driven by a change in anti-tank mine design. An anti-tank mine used in Angola against South African forces used an explosively formed penetrator or EFP. Similar mines were encountered in Bosnia by UN forces. The explosively formed mines encountered by the UN forces were manufactured by Yugoslavia and called a TMRP-6. These mines are capable of penetrating 55 millimeter (over 2 inches) of rolled homogeneous steel armor at a range of 2 meters (6 1/2 feet). This capability exceeded the thickness of the MRV hull, and that of most battle tanks of that period. The South African Denel group developed a modified design for the Mamba that used a composite steel-ceramic underbody shield weighing one ton. In addition to the added weight, the modification significantly decreased the ground clearance of the Mamba. Mechem developed a new design which used the anti-penetrator mine shield with a better ground clearance. This vehicle was called the Cougar. The Cougar was later produced in the US by Technical Solutions Group. The UK purchased eight of these vehicles in 2002, but called them Tempest (Ogorkiewiez 2008).

Ogorkiewiez states that the pace of MRV (or MRAP) development and the scale of their employment exploded after the invasion of Iraq in 2003, because of the IEDs used by Iraq insurgents. The use of IEDs was not anticipated by US forces. The most effective response to the use of IEDs proved to be the employment of South African designed MRVs (or MRAPs). The US Marine Corps purchased Cougars, from Force Protection in South Carolina, in 2004 for use in Iraq. The Cougar was designed to withstand an attack by two stacked anti-tank mines, or 14 kilograms of TNT or 31 pounds. Thirty pounds of TNT is comparable to the explosive force of three 120 MM mortar rounds. The Cougar withstood attacks in Iraq by IEDs exceeding 20 kilograms of TNT, one even withstood a IED with five 122mm artillery shells, with the explosive force of 23 kilograms of TNT or 50 pounds. The article states that during the two years that Cougars were employed by the Marines they did not suffer a single fatality. Requests for additional MRAPs were not approved until the beginning of 2007 (Ogorkiewiez 2008).

The US Army chose the Buffalo in 2003, a heavy 24 ton, 6X6 derivative of the Cougar. The Buffalo was fitted with a powerful hydraulic arm with a digger, and primarily used by engineer units for route clearance. By early 2007, there were over 90 Buffalos in use and they had survived over 800 IED strikes without a single casualty. The Army also started using RG-31s in 2003, and had purchased 246 by 2007, with 169 more on order. The survivability of Cougars, Buffalos and RG-13s, and the failure of other IED countermeasures, led to a decision by the US Department of Defense to set up a program for the large scale purchase of MRAPs in the beginning of 2007. They anticipated procuring a total of 17,000 vehicles (Ogorkiewiez 2008).

MRAPs are currently being produced in many countries. Production started in South Africa, and then migrated to the US. Now Thales Australian Land Systems are producing them in Australia. This is called the Bushranger, a 15 ton 4X4. Dutch forces have purchased 26 Bushrangers, and 700 are being used by the Australian Army. Krass-Maffei is producing a MRAP called the Dingo in Germany. The Marauder and the Matador are two new MRAP vehicles produced in a joint venture with South Africa's Paramount Group and Jordan's King Abdullah Design and Development Bureau. The article continues stating that in contrast to conventional armored vehicles MRAPs do not need to be stealthy or to have a low silhouette. Instead they need as much ground clearance as possible to allow the blast of the IED to dissipate before they hit the hull. The author states that a 4X4 design is also better for the same reason. He continues stating that many of the current MRAP designs are based on truck chassis for economy and speed of manufacture. This has resulted in some designs that appear ungainly of clumsy. The article stated that future MRAPs will be more refined, such as the Gefas being developed in Germany (Ogorkiewiez 2008).

There are also plans to expand the mission of the MRAP to include their current missions of route clearance, patrol vehicles, personnel carriers, ambulances, convoy escorts, and weapons platforms. The evolution of the MRAP is leading to a new class of light to medium weight armored vehicles. These vehicles are protected against mines, IEDs and other threats and better adapted than conventional armored vehicles to asymmetric warfare in the increasingly important urban terrain (Ogorkiewiez 2008).

The reasons for the development of the MRAP are given as a smaller scale of deployment, the deploying force had few armored vehicles, and the mine was the weapon

of choice for the insurgents being opposed. It is reasonable to assume that the arms embargo also had an impact. South Africa could not purchase armored vehicles from the global market so they had to develop a vehicle that would counter the IED threat that could be manufactured domestically. This vehicle was designed specifically to counter the land mine threat. It is also reasonable to assume that with the limited size of the South African Army, combat losses had a great impact, and provided a high degree of motivation for an effective countermeasure. The MRAP accomplished this mission. The early MRAPs were designed to withstand a charge of 46 pounds of TNT. It has already been discussed how five pounds of TNT can significantly damage a HMMWV. MRAPs in Iraq have encountered IEDs made from 500 pound aircraft bombs with approximately 189 pounds of TNT or the equivalent, and all the occupants walked away, while a M1A1 Abrams main battle tank struck by a similar sized IED, resulted in fatalities. Please see the enclosed illustrations of this event. There is a significant difference in the difficulty of making and emplacing a five pound device and a 500 pound device. The larger devices are harder to emplace and easier to detect.

Jeremiah Cushman maintains that, "the deadliest threat to US troops in Iraq has turned out to be roadside bombs, but there is a truck available with a V-shaped bottom that offers much better protection than armored HMMWVs. Indeed, not a single Marine has died while inside one of these combat trucks" (Cushman 2007). The article continues discussing how 200 prototype MRAPs have been deployed in Iraq since 2004, and they have worked so well the Pentagon is pressing several US companies to increase production. The Mine-Resistant Ambush-Protected (MRAP) vehicle program is a multi-service, billion-dollar effort to field these systems as quickly as possible to save soldiers

lives. The Marine Corps System Command serves as the lead organization (Cushman 2007).

The program commenced 9 November 2006, when the Army and Marine Corps released a competitive request proposals (REP). The bidders were asked to "produce mobile, multi-role vehicles built to survive mines, rocket-propelled grenades (RPG) and small-arms fire." The vehicles were to be designed around the distinctive V-shaped hull and raised chassis of previous MRAPs. The total order was for 4,060 vehicles: 2,500 for the Army, 1,022 for the Marine Corps, and 538 for the Navy (Cushman 2007).

The program divided the MRAPs into three categories. Category one is the smallest, consisting of a six man patrol vehicle, this has also been called the Mine-Resistant Utility Vehicle (MRUV). Category two is larger, designed to carry ten, and capable of missions other than just patrolling, such as an ambulance. Category three is the largest, designed for engineer use for route clearing, anti-IED operations (Cushman 2007).

Cushman continues that on 26 January 2007, nine companies were awarded contracts to produce four vehicles, two category one and two category two MRAPs for testing by April 2007, at Aberdeen Proving Ground, Maryland. The category three requirements were expected to be filled by Force Protection's Buffalo mine-clearing vehicle. The Navy and Marine Corps had already ordered 74 of these vehicles. The new contract was for an additional 36 vehicles valued at $34.6 million. Testing on the category three vehicles was expected to be completed by January 2008 (Cushman 2007).

Cushman quotes CPT Jeffery Landis, a spokesman for the Marine Corps Systems Command, for the reasons for awarding contracts to several companies. The objective

was to get the MRAPs into the hands of war fighters as soon as possible. By employing a number of companies, the military could harness several production lines. Using multiple companies also decreased the concern that one company would not have the required capacity. The companies selected included both large and small. The following companies had their bids selected:

> BAE Systems Ground Systems from York, Pennsylvania, was selected to build a category one called the RG-33, and a category two called the RG-33L.
>
> Oshkosh Truck from Oshkosh, Wisconsin, was selected to build a new Alpha in conjunction with Protected Vehicles as their category one, and the Bushmaster for their category two in conjunction with a Australian company.
>
> Textron Marine Systems from New Orleans, Louisiana, was selected to build a six and ten man variant of the M1117 Armored Security Vehicle (ASV).
>
> General Dynamics Land System-Canada (GDLS) from London, Ontario, Canada, was selected to build the GR-31 Mk 5 for their category one and the RG-31E for their category two.
>
> Protected Vehicles from North Charleston, South Carolina, was selected to build the Golan as their category two vehicle.
>
> Force Protection from Ladson, South Carolina, was selected to build 4X4 and 6X6 variants of the Cougar for their category one and two vehicles.
>
> Armor Holdings Aerospace and Defense from Arlington Virginia, was selected to build armored hulls to be fitted to chassis made by FMTV (Family of Medium Tactical Vehicles) from Sealy, Texas.
>
> General Purpose Vehicles from New Haven, Michigan, was selected to build modular vehicles.
>
> International military and Government from Warrenville, Illinois was selected to build a armored personnel carrier.

Soon after awarding the first contracts, the first low-rate initial product (LRIP) contracts were awarded to systems that met the requirements and were ready for deployment. The Marines also increased their requirement to 3,700 vehicles, for a total of 6,738. The first LRIP orders were received mid-February. Force Production was

awarded a $67.4 million contract for 125 vehicles, including 65 Cougar 4X4 category one, and 60 Cougar 6X6 category two systems. BAE Systems also received a $55.4 million deal for 90 vehicles, including 75 RG-33L and 15 RG-33s. At the end of February, three other contracts were awarded. Oshkosh Truck was awarded $30.6 million for 100 Alpha category one vehicles, Protected Vehicles was awarded $37.4 million for 60 Golan category two vehicles, and GDLS was awarded $11 million for ten RG-31 Mk5 category one and 10 RG-31E category two vehicles (Cushman 2007).

At this point in time there were 395 MRAPs in the pipeline, with more orders pending. Some analysts predicted the troops in the field would have difficulties with maintenance and logistics with the variety of models. The marines anticipated this, and required all MRAP designs to have common characteristics, such as diesel engines and drive trains. All MRAPs were sent to Charleston, SC where they would be equipped with a common communications package, including IED jammers. The possibility of eventually transferring some MRAPs to the Iraq security forces was also contemplated (Cushman 2007).

Cushman concludes the article stating that despite the emphasis placed on the MRAP program, the military has not finalized the funding plans for the program. Under the current budget, appropriations have been made to purchase 805 vehicles for the Marines, with another 244 in the wartime supplemental funding bill. The Army and Marines are asking for $2.2 billion and 2.8 billion respectively from their unfunded priorities list for MRAPs. Cushman states, “funding is affected by the status of the MRAP production within the Pentagon. Since it is not an official program, it is being funded primarily from supplemental requests” (Cushman 2007). If the program attained

formal status, it would secure a place in the Department of Defense's base budget and receive continued funding. Until this happens, the number of MRAPs that can be legally procured will be capped, according to Claude Bolton, the Assistant Secretary of the Army for Acquisitions, Logistics and Technology at that time. Cushman states that MRAPs have been able to defeat IEDs in Iraq, but they still have to "overcome the snags of the budget process in Washington" (Cushman 2007).

In his research project titled "*The Mine Resistant Ambush Protected Vehicle, A Case Study*," COL Michael Howitz focuses on the accelerated acquisition process used for the MRAP program. COL Howitz states that the MRAP rapid acquisition is one of the largest materiel acquisition programs since World War II and provides an example of how the US industrial base is agile. He states two examples of how problems were resolved in a lack of tires and a lack of steel, as support for this agility. This article is helpful in understanding the effort that went into accelerating the procurement process (Howitz 2008).

A 2008 GAO report states that 75 percent of casualties in current combat operations in Iraq and Afghanistan are caused by IEDs. The DOD initiated the MRAP program to mitigate this threat. In May 2007, the Secretary of Defense stated that the MRAP program was the single most important program. The report states that as of July 2008 $22 billion has been appropriated for more than 15,000 MRAP vehicles, and about 6,600 had actually been fielded. This equates to a cost of almost 1.5 million for each MRAP. The report examines the acquisition program. The report states that there may be supportability issues for the US Army due to the accelerated acquisition program (Sullivan 2008).

"Mine-Resistant, Ambush-Protected (MRAP) Vehicles: Background and Issues for Congress" by Andrew Feickert and discusses the evolving requirement for MRAPs (Feickert 2008). The Buffalo MRAP was originally intended to be used by Army engineer units. The Marine Corps decided in February 2007 to replace all HMMWVs in Iraq with MRAPs while the Army chose to continue to rely on armored HMMWVs. In March 2007, the MRAP requirement grew by 15 percent as the Navy, Air Force, and US Special Operations Command (USSOCOM) added requirements that totaled 7,774 as of 26 March 2007. The article states that in May 2007, the Army began considering replacing all HMMWVs in Iraq with MRAPs because of requests from commanders in the field. This would increase the requirement for MRAPs to 17,700 vehicles. On 28 June 2007, the Joint Requirements Oversight Council (JROC) endorsed a requirement to replace every HMMWV with MRAPs, potentially pushing the requirement to over 23,000 vehicles. The JROC capped MRAP procurement at 15,374 in September 2007, but allowed for changes based on requirements in Iraq and Afghanistan.

On 30 November 2007, the Marine Corps reduced their request for MRAPs to 2,300 vehicles from their original request for 3,700. The Marines gave six reasons. First, IED attacks had significantly decreased in the Marine area of operations over the last six months. Second, the MRAP was too heavy to operate off improved roads, in confined areas, or crossing most bridges. Third, there was a reduced need to expose Marines to high-threat roads because of the use of unmanned aerial vehicles (UAVs) and airlifting supplies. Fourth, effective counterinsurgency strategy requires Marines to operate on foot patrols and interact closely with the local populace. They stated the use of the MRAP inhibited this. Fifth, MRAPs associated with surge forces are not required. Last,

MRAP replacement numbers were lower than expected, because MRAP losses were lower than expected. The Marine reduction from 3,700 to 2,300 vehicles is anticipated to result in a cost savings of $1.7 billion. The article states that the Army increased their requirements for MRAPs from 10,000 in September 2007 to 11,953. The JROC authorized a range between 10,433 to 15,884, for the Army. The JROC also approved a reduction in Air Force MRAPs from 697 to 558 vehicles, and the Navy's and USSOCOM's requirements remained unchanged at 333 vehicles.

It is interesting to note that a 29 April 2009 article by Fred Baker titled "Marines engineer Afghanistan worthy MRAP" states that Marine Corps Commandant General James T. Conway wants an off-road version of the MRAP for the Marine Corps to operate in Afghanistan. The Marines will try to modify their existing MRAPs with independent suspension to improve their off road performance. The article states the Marines plan to modify 2,200 MRAPs they do not need in Iraq (Baker 2009).

Feickert also discusses MRAP survivability. It quotes DOD officials stating the casualty rate for MRAPs at 6 percent, compared with 15 percent for the M-1 Abrams main battle tank, and 22 percent for the up armored HMMWV. The DOD continued stating that more than 150 attacks have been recorded on MRAPs, only seven occupants have been killed (Feickert 2008). The author of this report was not able to find any unclassified data to support these percentages.

Feickert addresses the question regarding DOD's long term plans for MRAP. It quotes senior Army officials that stress that the MRAP was only an "interim strategy" and that the Army is still "dedicated to the future of the Joint Light Tactical Vehicle, the HMMWV's replacement" (Feickert 2008, CRS-5,6). Fieckert continues with questions

about integrating the MRAP into the force structure, or placing them in reduced readiness after Iraq.

A Center for Strategic and Budgetary Assessment report published in 2008 begins with a statement that simple solutions so complex problems seem attractive but are almost always wrong. The report goes on to state that political and military leaders are struggling with the problem of how much to invest in the MRAP, without undermining the ability of the force to conduct its current mission, and the force's ability to be effective across the full spectrum of conflict. The report does not seek to determine what mix of armored vehicles are needed, but will provide information for others to draw their own conclusions (Wood 2008).

A 2008 USA Today article begins with the statement that roadside bomb attacks and fatalities in Iraq are down by almost 90 percent over the last year, according to Pentagon records. In May 2008, eleven US troops were killed by IEDs, compared with 92 in May 2007. The article states several reasons for this drop. The first is the MRAP with almost 7,000 rushed to Iraq during the year. "MRAPs have taken many hits that would have killed soldiers," stated Adm. Michael Mullen, chairman of the Joint Chiefs of Staff (Brook 2008). The second reason is Iraq security forces, providing intelligence to find IEDs and those that make and emplace them. Next is improved surveillance from fixed security cameras and UAVs. The use of MRAPs has caused the insurgents to use larger IEDs, which provide US forces a better chance of apprehending those that make and emplace IEDs. The article concludes that the IED may have been defeated by the MRAP, but it is not going away (Brook 2008).

The following graph shows the decrease in IED deaths compared to the fielding of MRAPs and change in troop strength. IED deaths are from icasualties.org (icasualties.org. 2009), and shown in blue. MRAP fielding is shown as constant until July 2007 when the mass fielding started and then at a consistant increase until the 10,000 MRAPs were fielded by Febuary 2009. The number of MRAPs fielded is divided by 100 to compare with the IED deaths and shown in red. Troop strength is from the March 2009 “Measuring Stability and Security in Iraq” report to Congress (Department of Defense 2009) and shows monthly troop strength divided by 1,500 to compare with IED deaths and shown in green. This chart shows the significant decline in IED deaths as the MRAP was being fielded. These is no evidence that the MRAP fielding alone caused this sharp decline, but there is support that there was an impact. The quarterly stability report also has a chart that shows IED attacks, which declined within the same time frame that IED deaths did. IED attacks did not decrease at the same rate as IED deaths. This further supports the thesis that the MRAPs had a significant effect in preventing IED deaths and protecting troops from the IED threat.

A 2009, USA Today article quotes Defense Secretary Robert Gates that soldiers in MRAPs are four times more likely to survive a roadside bombings (IED) than those in HMMWVs. An Inspector General’s report released in December 2008 found that Pentagon leaders knew in the early 1990s that HMMWVs, because of their low ground clearance, flat bottoms and light weight, were “death traps” when struck by IEDs (Brook 2009).

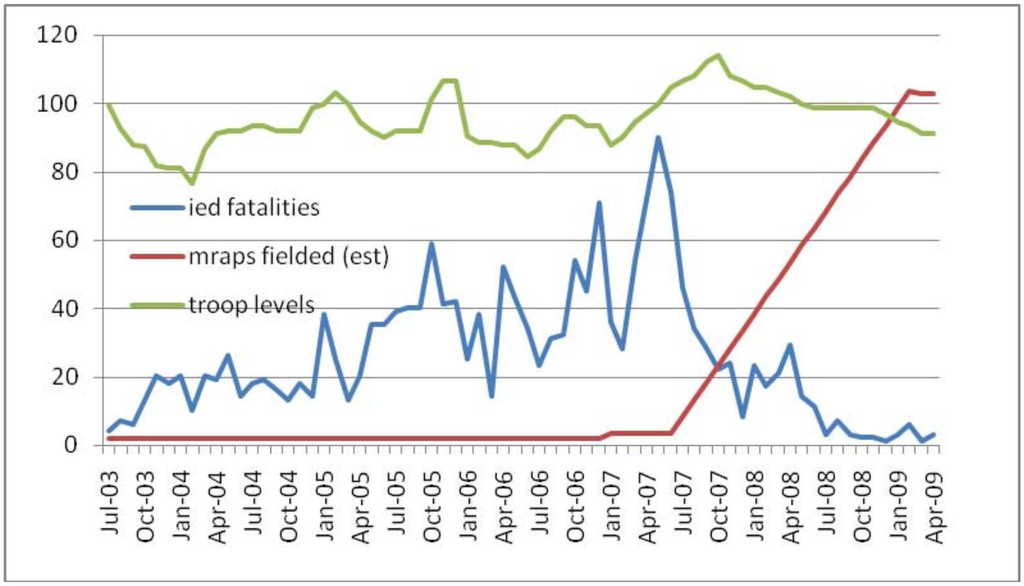

Figure 1. IED Fatalities/MRAP Fielding/Troop Levels
Source: icasualties.org, *IED fatalities by month* http://icasualties.org/Iraq/IED.aspx (accessed April 27, 2009).

The first MRAP, other than those assigned to engineer units, was fielded in April 2007, and since then 11,700 have been fielded between Iraq and Afghanistan. Training of more than 22,000 personnel was included in the fielding. MRAPs have been adapted with upgraded armor, better suspension, improved seats, safety harnesses, gunner's restraints, and improved night driving capability. The MRAPs have maintained a 95 percent operational readiness rate (Multi-National Corps – Iraq Release 2009).

An interview with Gary Coleman and Richard Owen from MRAP program manager's (PM) office provided information about the MRAP program (Owen 2009). MRAPs were identified as a specialty vehicle limited to engineer units for purposes of clearing routes. Requests were made for additional MRAPs to counter the IED threat, but were denied. The reason for this is that it was thought that the armored HMMWV would be effective and that there was no production base to produce the quantities of MRAPs

that were being requested. The armored HMMWVs could be readily mass produced. The armored HMMWV proved ineffective, partially due to its design with a large flat bottom relatively close to the ground which absorbed a significant portion of the blast effect (Owen 2009).

Mr. Coleman and Mr. Owen discussed how the challenge of the MRAP program was to balance protection, load carrying capacity, mobility, and supportability in the development of the MRAP. The question they recommended that deserved attention is: does the MRAP vehicle provide the best set of trade-offs consistent with the Army's needs to protect troops from the IED threat. They recognized that protection was the priority. Supportability was the lowest priority. This is evident in both the high fuel consumption rate, and in the lack of repair parts and training.

The rapid acquisition of the MRAP was also discussed. Mr. Coleman and Mr. Owens stated that they looked at the MRAP acquisition as an evolutionary process, with successive generations that improved as technology was perfected. They stated that the majority of the technology for the MRAP was mature when the program started. Their priority was establishing a production schedule and maintaining it. Other programs that are developing new technology are more revolutionary in nature, and focus on performance. The MRAP PM focused on getting the first generation produced, and then established enhancements that would be incorporated in future generations.

Comments from the warrant officers responsible for maintaining MRAPs are generally positive (System 2009). CW2 Kerry Murray is the 1 BCT 10th Mountain maintenance technician. He states that the MRAPs were pushed out so fast that the repair parts supply system could not keep up. He also states that he understands that this speed

was necessary to save lives, and the rest can be figured out later. WO1 Mike Sanford is the maintenance technician for B Company 801st BSB. He states that he has had maintenance problems with the electrical system which was not designed for the harsh environment in Iraq, and delays in getting repair parts. He notes that changes have been made to correct problems in the electrical system. He concludes his remarks with the statement that he is impressed with the MRAP as it does what it was designed to do, saving lives from IED attacks. CW3 Jason Dunn is a communications technician with the 93rd Signal BDE. He had significant issues with the non-military electrical system. He recommends modifying the vehicles electrical system to be more like other military vehicles. CW3(R) Al Smith a Senior System Analyst at Aberdeen Proving Ground states that MRAPs fill a niche, theater need and increase the chance of coming away from an IED attack. CW2 Jeff Wargo is a Combat Repair Team Chief for 2/1 CAV. He states that a lack of repair parts is the biggest problem. He also states that the limited training provided when the MRAP was fielded was inadequate. He concludes his comments with the statement that he loves the MRAP, they save lives, but someone failed on parts and sustainment of this equipment.

The MRAP is a vehicle that is designed to survive an IED attack. The identifying components include a V-shaped bottom, a high ground clearance, and wheel and axle assemblies that are designed to detach from the vehicle during an IED attack. These components focus on limiting the absorption of the blast effect. MRAPs also have protective measures in the crew compartment to limit injury from an IED blast.

The future of the MRAP is yet to be determined though the Secretary of Defense, Robert Gates, has directed that they be incorporated in the future US Army. Originally,

the MRAP PM stated that the MRAP was only expected to be used for a short period and then retired. As the investment in MRAPs increased, and the MRAP design evolved, they have been identified as filling a future requirement. The trade-offs that the MRAP PM discussed are being readjusted. The mobility factor is gaining priority, as is supportability. Advancing technology is making the current generation of MRAPs able to provide greater levels of protection in addition to mobility and supportability. There is a future for the MRAP. John Bennett quotes US Defense Secretary Robert Gates when he states that MRAP capabilities should be incorporated in any future US Army vehicle program (Bennett 2009).

Research Questions

The primary research question of: does the MRAP meet the US Army's needs as the primary method of protecting troops from the IED threat, can be answered by addressing the three secondary questions. The first secondary question of the IED threat has been analyzed including both the physical and psychological aspects of the IED attack. The primary destructive force is the blast effect which is most effective against large flat bottoms of the majority of military vehicles. The second secondary question of non-MRAP IED countermeasures have been analyzed including adding armor protection to existing equipment, IED focused training, trigger disruption technology, and use of experts such as engineers. Each of these countermeasures had a measure of success, but individually or combined they were unable to significantly impact IED casualties. The third secondary question of the capabilities of the MRAP found that it was specifically designed to counter the IED or land mine threat. The MRAP provides the best protection for troops from the IED threat. The other non-MRAP countermeasures make significant

contributions to countering the IED threat, but the MRAP has proven the most effective of all the IED countermeasure methods. This is not to imply that the MRAP alone is the best method of protecting troops, for the best method is a combination of all IED countermeasure methods. The future IED threat will continue to adapt, but it is not going away. Requested changes to the MRAP design, for a lighter and more mobile vehicle, support the assumption that the MRAP will meet the Army's needs to protect troops from the IED threat in the future.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of this research is to answer the question: Is the MRAP the best method of protecting US troops from the IED threat. This study has looked at how the US Army has suffered many casualties from Improvised Explosive Device, (IED) attacks in their operations in Iraq and Afghanistan. The most common vehicle used at the start of the operation to transport troops, the High Mobility Multipurpose Wheeled Vehicle, (HMMWV) had no IED protection. To compensate the US Army has utilized many different approaches to protect troops and counter the IED threat. The first approach used was to add additional protection, the second was additional training, the third was to interfere with the triggering method, and fourth is to use experts such as engineers. These proved ineffective, IED deaths continued to increase. The US Army turned to the MRAP, and IED deaths significantly fell.

The result of this study provides US Army personnel information about the IED threat, non-MRAP IED countermeasures and, the history and capabilities of the MRAP. This study also provides decision makers with an understanding of the force protection needs the US Army has, as well as some of the effects that the MRAP program has had on the US Army and may have in the future.

The previous chapter compared requirements to protect troops from the IED threat against the capabilities of the non-MRAP countermeasures and the MRAP. The specific requirements focus on protection, rapid fielding, and supportability. The MRAP is the superior choice at protection and rapid fielding, but it lacks supportability.

Interpretation of Findings

The MRAP meets the US Army's needs as the best method of protecting troops from the IED threat. This does not imply that other non-MRAP IED countermeasures are without value. The IED countermeasures should include multiple efforts, IED awareness training, electronic countermeasures and engineer support. Nevertheless, the best method, the method that has proven to be most effective, is the materiel solution of using the MRAP.

The MRAP's acquisition approach of evolutionary as opposed to revolutionary is able to continue to improve on the MRAP design. This enables the MRAP to adapt to changes in insurgent tactics. This also enables the MRAP to adapt to alternate operational environments. This ability to adapt and improve as technology develops, will promote the MRAPs use in the future. The MRAP was designed from inception to counter the IED threat. It has proven effective for this purpose.

The implications of these findings are that as the MRAP is more widely used, and insurgents react by using larger IEDs, they will become more vulnerable to the other non-MRAP countermeasures. MRAPs protect troops from IEDs, and cause insurgents to assume additional risk to attack them.

Recommendations

Further study into the optimal trade-off for US Army vehicles between protection, load carrying capability, sustainability, and mobility would prove beneficial for future vehicle developments. This approach seems to be suggested by the comments of Defense Secretary Robert Gates when he directed that MRAP lessons learned be incorporated into future US Army vehicle designs (Bennett 2009)

Further study into the future of the MRAP may also be of use. The US Army has made a significant investment in the MRAP, and has been directed to institutionalize the MRAP (Engelbrecht 2009). This would imply that MRAP repair parts would be incorporated into the US Army materiel system. MRAP will be included in mechanic training. Units should have MRAPs on their modified table of organization and equipment (MTOE).

Summary and Conclusions

Based on the requirements of protection, rapid fielding, and supportability the MRAP has the capabilities to effectively counter the IED threat while protecting US troops. Non-MRAP countermeasures do not have the capabilities to meet these requirements. The MRAP alone is not able to counter the IED threat, but as a component of a comprehensive effort, it has proven effective. The MRAP is the most critical component of the US Army's combined anti-IED effort.

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Soldiers survived!!

This is one of the new "hardened" MRAP vehicles that was hit by a 500 lb bomb (IED). The vehicle was totally destroyed, but EVERYONE IN THE VEHICLE WALKED AWAY.

Note the unusual construction of the bottom of the hardened Pathfinder APC. Note the bottom looks like the hull of a ship. The blast picked up the truck and turned it around! The driver got some broken ribs (see the photo of the steering wheel), but that's it. Everyone walked away from a 500 lb explosion directly beneath their vehicle.

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